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PAPERS AND PROCEEDINGS OF

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September 1981

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ROYAL SOCIETY OF TASMANIA

ANNUAL REPORT FOR THE YEAR 1980

The Council has the honour to present to members the following reports on the activities of the Society during the year.

COUNCIL AND OFFICE BEARERS

Patron

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President

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Sir Stanley Burbury

Vice-Presidents

Mr R.J. Downie
Mr D.R. Gregg

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Dr E.A. Colhoun
Mr A.J. Dartnall (to 6.5.1980)
Mr G.E.A. Hale
Mr E.H. Norton (to 31.5.1980)
Mr K.E.J. Robinson
Dr Jocelyn Townrow
Mr L.E. Wall (from 1.7.1980)
Mr R.E. Ward
Mr P.G. Webb

Honorary Secretary
Mr D.R. Gregg

Honorary Treasurer
Mr T.A.H. Knight

Honorary Auditor
Mr D.B. Churchill

Honorary Editor
Dr M.R. Banks

PRESIDENT

Sir Stanley Burbury took the Chair, as President of the Society, at the Annual General Meeting in March. He also took the Chair at the Annual General Meeting of the Northern Branch in March.

ERNEST HARRY NORTON

Mr E.H. Norton died on 31 May 1980. He was an enthusiastic supporter of the Society since he joined in 1947 and was a member of the Council since 1978.

ANNUAL MEETING

At the Annual Meeting on 4 March, Dr E.A. Colhoun retired as Vice-President, and Mr S.J. Thrower and Mr J.D. Thomson as Members of the Council. The following were elected:

Vice President	Mr D.R. Gregg
Members of Council	Dr E.A. Colhoun
	Dr Jocelyn Townrow
Honorary Secretary	Mr D.R. Gregg
Honorary Treasurer	Mr T.A.H. Knight
Honorary Auditor	Mr D.B. Churchill

REVIEW OF RULES

The Council accepted the recommendations of the Committee set up in 1978 and the proposed changes to the Rules are to be placed before the 1981 Annual General Meeting.

BICENTENNIAL OF FOUNDATION OF AUSTRALIA

The Council has proposed that a lecture honouring Sir Joseph Banks mark the bicentennial in 1988 of the European settlement of Australia. The proposal has the support of the Australian Academy of Science and the Royal Societies in other States. An approach has been made to the Australian Bicentennial Authority for funding of the project.

LECTURES

The following lectures were given at General Meetings during the year:

March	"The Rise and Fall of the Hobart Town Rivulet: a historic preservation study."	Mr John Button Howroyd & Forwood Architects
April	"Sudden Infant Death Syndrome."	Dr Neville Newman Royal Hobart Hospital
May	"Re-unite Gondwana - the role of Antarctic geology in piecing together the southern continents."	Professor James Collinson Ohio State University
June	"Ocean Waves for Power in Tasmania."	Dr R. Underwood Hydro-Electric Commission
July	"Environmental protection in the uranium mining province of the Northern Territory."	Dr David Thomas University of Tasmania
August	"Drugs of Plant Origin."	Dr B.K. Bhat University of Tasmania
September	"The use of nematodes for the biological control of insect pests."	Dr Robin Bedding CSIRO
October	"Landforms in the National Estate."	Professor J. Jennings Australian National University
November	"Plant diseases as allies: new prospects and old problems in biological control."	Mr Ian Geard Department of Agriculture

LIBRARY

The Library has continued to function smoothly during the year under the direction of the new Librarian, Mrs Mary Marshall.

Early in the year the current serials display rack was replaced by a more suitable one for the area, and this, positioned against the wall, leaves more free space in the library. The old photocopier has also been replaced, not by a new model, but by one in good working order. It is in constant use. A group of carrels was also removed and replaced by a table, more suitable for Royal Society readers.

During the year the Bindery has made a special effort to make inroads into the mass of Royal Society material awaiting binding. The result, 2015 volumes bound during 1980, is a record. Many long and dilapidated runs have thus been saved from further deterioration, and the serials collection as a whole looks much better. There are however still several thousand volumes in need of binding.

In August copies of the latest Papers and Proceedings were mailed to 233 exchange partners, and two new exchanges were established during the year, one with the Kansas Academy of Sciences and one with the Nanking Institute of Geology and Palaeontology. Two more exchanges are at present being arranged.

Towards the end of the year the takeover of the TCAE library necessitated considerable alterations to the University Library as a whole. University Archives has now been moved to the top floor next to the Royal Society Library, and has incorporated a small section of it. The resultant loss to the Royal Society Library of 36 metres of shelving will necessitate reshelving of the serials collection, a job which will be undertaken during the first few months of 1981. At the same time it is proposed to interfile quarto and octavo serials, making one sequence. Monographs will still be differentiated according to size.

During the year 498 visits by members of the Society, University Staff and students and other users were recorded in the Register of Users. The Library supplied 198 items in response to interlibrary loan requests in the course of the year.

Opening hours of the Library have now been amended to 9-1 and 2-5, Monday to Friday.

PUBLICATIONS

Volume 114 of the Papers and Proceedings was published in May 1980. It contained 16 papers by 18 authors and totalled 233 pages.

At the end of 1980, ten papers had reached proof stage and another seven were in varying stages of editorial processing.

MEMBERSHIP

The membership is 471, a decrease of 35, and is made up as follows:

	Northern Branch	Total
Honorary Life Members	2	7
Life Members	8	36
Ordinary Members receiving the Papers and Proceedings	61	250
Ordinary Members not receiving the Papers and Proceedings	87	158
Associate Members	17	20
	175	471

COUNCIL MEETINGS

The Council met three times during the year with Mr R.E. Ward and Mr P.G. Webb representing the Northern Branch on the Council. A meeting was held in Launceston on 5 September 1980 when the Council inspected the Northern Branch Library.

NOMINEES TO OTHER BODIES

The Council re-elected Dr M.R. Banks and Dr D. Martin to the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

> The 1980 State Budget dealt a severe blow to the Tasmanian Museum and Art Gallery with an increase in the Government grant on only $10,000, bringing the 1980-81 grant to $630,000. This is the lowest percentage increase in the grant since at least 1942. A small additional grant for capital works of $25,000 has enabled the renovation of the ground floor of the Queen's Warehouse at 40 Macquarie Street to be completed but further renovation of the Commissariat Store buildings has had to be suspended.
>
> No funds were made available by the State Government to enable the repair and renovation of the Zeehan Post Office building for extensions to the West Coast Pioneers' Memorial Museum. The Government did, however, provide funds for the purchase of a house at Zeehan for the use of the new Curator, Mr L.H. Procter.
>
> The Trustees have instituted drastic reductions in discretionary expenditure to ensure that the Museum and Art Gallery will continue to provide a serivce to the people of Tasmania even if this is at a lower level than it has been in recent years.
>
> During 1980, visitors to the Tasmanian Museum and Art Gallery totalled 130,791, an increase of 14,522 over the figure for 1979. The attendance at the West Coast Pioneers' Memorial Museum at Zeehan was estimated at 126,000 for the 1979-80 financial year.
>
> *America and Europe: A century of Modern Masters* from the *Thyssen-Bornemisza Collection* attracted record numbers of people to the Museum and Art Gallery and was seen by 28,208 visitors during the twenty days it was on view.
>
> Dr Banks was re-elected Chairman of the Trustees. There have been further changes in the membership of the Board. Sir Peter Crisp resigned in 1980 and has been replaced by Mr M.R. Wright of Devonport. Mr Derek Holden of Launceston has replaced Dr D.F. Smith. Mr J.E. Tomlinson has replaced Mr G.C. Cramp. Mr A.D. Haigh, appointed by the Hobart City Council, has been replaced by Mr John Kennedy.
>
> Mr Carl Andrew, Curator of Art since 1975, resigned and has been replaced by Mr Hendrik Kolenberg. Mr Peter Boyer, Curator of Museum Display, and a member of staff since 1973, has also resigned and has been replaced by Mr David Ellis. Ms Jane Burrell, Designer and a member of staff since 1972, resigned and has been replaced by Mr Adrian Spinks, appointed as Display Assistant.

Dr Jocelyn Townrow continued as the Council's nominee on the Board of Trustees of Royal Tasmanian Botanic Gardens. She reports on the year's activities:

> The improvement in the Gardens evident since the present Superintendent's appointment has been maintained over the past year, and is reflected in a 6.5% increase in visitors (approximately 175,700 metered).
>
> The Superintendent, Mr A.P. May, has been awarded a Churchill Fellowship and will be visiting botanical gardens in Europe, United Kingdom and U.S.A. in early 1981, particularly garden areas for the disabled and for the blind.
>
> Mr B. Lumb, Assistant Superintendent since October 1979, resigned after eight months service.

Popular developments include completion of the "Wombat One" shelter, designed and built by a TCAE team led by Mr R. le Plastrier, redesign of the Conservatory fountain, installation of wrought iron fencing in keeping with the front entrance main gates, refurbishing of the Fuchsia House, Monel tiling of the road in the Rose Section, and most recently a new fernery on the south side of the Lily Pond. Plans are in hand for the development of the Aboriginal Midden Site at the northern end of the Gardens excavated by Tasmanian Museum archaeologist, Dr P. Murray. Rare endemic plants are being collected for conservation and future display. Two of the oldest and largest trees, the *Pinus longifolia* next to the Tea Room, and the *Salix babylonica* opposite the Rose Section, were severely storm damaged and had to be removed in November.

The Trustees are greatly concerned over the acute inadequacy of the main public toilet facilities both in size and disposal of sewage.

Vandalism continues to be a problem with the theft of choice plants, damage to buildings and defacement of plaques and labels.

The Museum and Education Centre has proved popular especially for school tours. 1,777 children and 198 teachers from 50 southern Tasmanian schools visited the Museum under the guidance of Education and Information Officer, Mr M. Hurburgh. A total of 15,000 persons, representing about 11.6% of Garden's visitors, have viewed the Museum exhibits and new displays.

The State Government budget allocation for 1980/81 was $500,000 and capital expenditure once again suffered major consequences of insufficient funding, halting the continuing work on upgrading of roads, pathways and kerbing necessary for public safety especially of the handicapped, preventing the replacement of the nearly derelict depot area and No.4 glasshouse, and foreshadowing retrenchment of at least three employees. The appointment of a Senior Foreman to replace the Assistant Superintendent has been made possible through the resignation and non-replacement of four employees prior to Christmas.

Restoration of the historic Arthur and Eardley Wilmot walls is in progress and has been funded wuth $6,500 from the National Trust Preservation Fund (Hobart), while a retaining wall around the Lower Domain Road boundary erected by the Hobart City Council was funded equally with $6,000 each from the H.E.C. and the Gardens. At the end of December the State Government announced a grant of $8,000 for the development of a garden for the disabled.

The Board of Trustees has learnt, with regret, of the resignation of Mr Max Angus after many years of valuable service and welcomes Commander G.B. Campbell in his place. A new sub-committee, chaired by Dr Townrow, has been formed to determine the long-term development, coordination and integration of the Gardens. It's chief goals are improvement of essentially botanical aspects of the Gardens and integration of projects; preliminary mapping of the Gardens is in hand.

NORTHERN BRANCH

Chairman	Mr D. Walter
Vice Chairman	Mr B.A. Pike
Past Chairman	Mr H.S. Payne
Council Members	Mrs B. Davies
	Mr D.G. Hannan
	Mrs S.M. Dent
	Mr R.E. Ward
	Mr E.H. Fist
Honorary Secretary	Mr P.G. Webb
Honorary Treasurer	Mr K.E.J. Robinson
Honorary Auditor	Mr H.C.A. Pitt
Representatives of Branch on Council:	Mr R.E. Ward
	Mr P.G. Webb

The Branch Council met three times, the principal business, other than routine matters, being to arrive at a firm policy for the library, housed in the Northern Regional Library. To consider this matter, a meeting of the Society's Council was held in Launceston in September 1980.

At the 1979 Members' Night meeting, a proposal to change the night of meeting was raised by Council. The meeting decided to seek the views of members, so a questionnaire was issued to all Northern Branch members. 23% responded and expresssed overwhelming preference for retention of the first Friday for meetings.

The following lectures were given at General Meetings:

March	"Religious Groups in Tasmanian History."	Mr H.S. Payne
April	"Dean of Scotch."	Mr B.A. Pirkis
May	"Electricity Supply in Tasmania until the Twenty-first Century."	Mr W.A. Gaskell
June	"The Sky at Night" - given in association with a display at the Planetarium	Dr R.P. Rodgers
July	"Computers, Communities and Crystal Balls" - lecture followed by demonstration at the TCAE Computer Centre	Mr J.M. Rose
August	The Report of the Museums and Art Galleries Advisory Committee	Mr K.E.J. Robinson
September	"The City in an Era of Restricted Oil Usage."	Dr Trevor Lee
October	"Landforms in the National Estate."	Prof. J.N. Jennings
November	"The Social Significance of the Family Law Act."	HH Mr Justice E.G. Butler
December	Members' Night -	
	"The Initial Teaching Alphabet."	Mrs P. Little
	"Some Museums in Great Britain."	Mr B.A. Pike
	"The Endangered Pheasant."	Mr P. Manchester
	"Guatemala."	Mr T. McGlynn

Excursions: One meeting was held at the TCAE, where members were conducted around the Computer Centre and saw demonstrations of its operations, following a lecture by the Manager.

A very successful excursion to the Northwest Coast was held in the November long weekend. Attended by some 25 members, including the Secretary, Mr D.R. Gregg, and his family, the excursion was based at the Seaway Motel, Boat Harbour Beach. It consisted mainly of two full-day trips. The first, by bus, was under the guidance of Forestry Officers from Smithton, and members investigated the Arthur River State Forest; the second was a walking tour, under the guidance of the Burnie Field Naturalists Club, of the Rocky Cape National Park.

Two further Bulletins were issued for sale to members: "Religious Groups in Tasmanian History" and "Computers, Communities and Crystal Balls". An earlier bulletin, "Astronomy, the Oldest and Youngest Science" was re-issued; stocks of earlier bulletins were also released for sale to members.

ACKNOWLEDGEMENTS

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, and the Queen Victoria Museum and Art Gallery are specially thanked for their help and cooperation.

R.J. Downie
Senior Vice-President

D.R. Gregg
Honorary Secretary.

BALANCE SHEET AS AT 31 DECEMBER 1980

1979			1980	1979		1980
53 051.50	Accumulated Funds		54 470.94	33.00	Cash on Hand	33.00
65.00	Subscriptions in advance		100.00		Cash at Bank:	
	Trust Funds:			4 690.74	- General Account	1 343.59
1 315.39	- Clive Lord Memorial Fund	1 352.14		2 224.70	- Papers & Proceedings Account	3 135.37
2 102.90	- A.N. Lewis Memorial Fund	2 208.70		658.66	- Clive Lord Memorial Fund	713.45
925.07	- Morton Allport Memorial	980.29		1 050.17	- A.N. Lewis Memorial Fund	1 198.84
391.27	- A.A. Clark Bequest	411.27		860.00	Mortgage Loan	860.00
2 622.80	- Joseph Milligan Bequest	2 753.90			Commonwealth Treasury Bonds	
1 356.44	- R.M. Johnston Memorial Fund	1 435.86		10 440.00	& Inscribed Stock (at cost)	14 440.00
590.12	- Henry Oliver Bequest	634.32		7 000.00	Interest Bearing Deposits	7 000.00
1 436.73	- W.H. Hudspeth Memorial	1 493.13		15 000.00	Library (at valuation for insurance)	15 000.00
2 176.70	- Life Membership Fund	2 273.70	13 543.31	24 076.65	Publications (at selling prices)	24 390.00
$66 033.92			$68 114.25	$66 033.92		$68 114.25

GENERAL ACCOUNT TO 31 DECEMBER 1980

Balance brought forward		4 690.74	Stationery		307.80
Subscriptions -			Insurance		119.69
236 @ $12	2 832.00		Attendants' fees		205.91
155 @ $8	1 240.00		Secretarial fees		200.00
18 @ $5	90.00		Lecturer's expenses		251.50
Other years	352.61	4 514.61	Management fee		1 450.00
			Post box rental		109.00
Interest		1 080.11	Postage and freight		680.51
Sales of publications and			Investments		4 000.00
Papers & Proceedings		1 948.73	Photocopying		119.45
Government Grant		1 450.00	Subscriptions		599.87
Rent		227.98	Printing of Papers & Proceedings		6 401.80
Miscellaneous		241.95			
University subsidy		1 635.00			14 445.53
			Balance carried forward		1 343.59
		$15 789.12			$15 789.12

PAPERS AND PROCEEDINGS ACCOUNT TO 31 DECEMBER 1980

Balance brought forward	2 224.70		
Interest	910.67	Balance carried forward	3 135.37
	$3 135.37		$3 135.37

ACCUMULATION ACCOUNT - YEAR ENDED 31 DECEMBER 1980

Balance	1 January 1980		53 051.50
Deduct	Net increase in advance subscriptions	35.00	
	Net transfers to Trust Funds	625.89	
	Decrease in cash at banks	2 233.02	2 893.91
			50 157.59
Add	Net increase in valuation of publications for sale	313.35	
	Increase in investments	4 000.00	4 313.35
Balance	31 December 1980		$54 470.94

NATIONAL MUSEUM
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Papers and Proceedings of the Royal Society of Tasmania, Volume 115, 1981

(ms. received 24.7.1980)

PODOCARPUS AND OTHER HIGHLAND PLANTS IN EASTERN TASMANIA RELICTS FROM LAST GLACIAL TIMES?

by M.K. Macphail and A. Moscal
University of Tasmania and 10 Midway Rd, Midway Pt.

ABSTRACT

McPHAIL, M.K. and MOSCAL, A., 1981 (30 ix): *Podocarpus* and other highland plants in eastern Tasmania - relicts of Last Glacial times? *Pap. Proc. R. Soc. Tasm.*, 115, 1-3. ISSN 0080-4703. Department of Geography, University of Tasmania, Hobart and Midway Point, Tasmania, Australia.

Podocarpus and other typically highland plants found growing at low elevations on the East Coast are probably relict from last glacial times. Their occurrence demonstrates the importance of plant competition in determining community composition and the need for caution when using modern botanical data to interpret the fossil record.

INTRODUCTION

In April of this year the shrub conifer *Podocarpus lawrencii* and the composites *Cotula alpina* and *Celmisia longifolia* were found (A.M.) growing at low elevations along the Douglas River in eastern Tasmania (41° 48'S; 143°55'E). Further collecting by Mark Noble (Australian National University) revealed a third unexpected composite, *Gnaphalium umbricola*, and the fern *Blechnum penna-marina* in the same area. Since all are typically subalpine-alpine species (see Curtis 1956, 1963; Jones and Clemesha 1976) their occurrence at low elevations calls for some comment.

LOCATION

The Douglas River rises in the low (maximum elevation 720 m) dissected plateau terrain south of Fingal Tier and flows southwards to reach the east coast in Maclean Bay, 10 km north of Bicheno. The source of the river is the Thompson Marshes but towards the middle and lower reaches the river is deeply incised into the plateau, flowing over several low waterfalls within a deep, shaded gorge. Both habitats are cool and moist, affording protection from fire, in contrast to the usual warm, subhumid and fire-prone environments of eastern Tasmania (Gentilli 1972). This is reflected in the composition of the riparian vegetation. The lower sector of the Thompson Marshes supports a heathland of *Leptospermum lanigerum-Melaleuca squarrosa-Callistemon viridiflorus* below scattered *Eucalyptus rodwayi* whilst riverbank communities downstream are mostly closed scrub and heath, usually *Notelaea ligustrina, Pomaderris apetala* and *Leptospermum lanigerum* but with some stands of *Nothofagus cunninghamii* and *Atherospermua moschatum*. The main *Podocarpus* stands occur above the waterfalls, growing on dolerite at about 420 m elevation. These consist of shrubs up to 2 m tall within *Nothofagus cunninghamii-Atherosperma* closed scrub, Individual *Podocarpus* shrubs are also found much lower down - to about 80 m elevation - and growing on sandstone and river gravels. Some are within reach of flood water and are shaped accordingly. The composites occur at elevations both higher and lower than *Podocarpus: Cotula alpina* and *Celmisia longofolia* in the lower Thompson Marshes at about 440 m, *Gnaphalium umbricola* and (*Blechnum penna-marina*) at about 60 m elevation. These elevations are compared with the altitudinal ranges of the same species on the north-facing slopes of Ben Lomond in table 1.

DISCUSSION

The Douglas River *Podocarpus* is the most easterly stand of the species known to date and, at 80 m, amongst the lowest in elevation in Tasmania. Other records for eastern Tasmania are uniformly on mountain summits and often in relatively exposed situations, e.g. at 1130 m on Mt Wellington and above 1380 m on the north-facing slopes of Ben Lomond (table 1).

TABLE 1

Plant Species	Altitudinal Range (metres above sea-level)	
	Douglas River	Ben Lomond (north-facing slopes of)*
Blechnum penna-marina	*ca* 60	1040-1560 (also at Lake Leake and in Fingal Valley)
Celmisia longofolia	*ca* 440	1100-1570
Cotula alpina	*ca* 440	1020-1565 (also Midlands)
Gnaphalium umbricola	*ca* 60	1100-1300
Podocarpus lawrencii	80-420	1380-1545

* M. Noble (pers. comm.)

Although *Podocarpus* occurs relatively close to sea level in western Tasmania and at about 240 m elevation in the Cubits Sugar Loaf - Long Ridge area behind Deloraine (W.D. Jackson pers. comm.), these occurrences are more obviously related to a downslope extension of cold, wet climates or (unlike the Douglas River stands) relatively close to highland vegetation containing the conifer. Nevertheless the species will grow well in cool, shaded garden situations near sea-level in Hobart.

These considerations suggest that relative freedom from plant competition as well as climate is important in determining the present distribution of *Podocarpus*. Significantly, the wiry habit of the plant enables it to withstand periodic extreme conditions such as flooding. The question is therefore not why *Podocarpus* can survive along the Douglas River but how (and when) the species came to be established there. Two possibilities exist:
(a) the stands are the result of a fortuitous but relatively recent arrival of seed from distant highland stands, or
(b) the stands have survived from an earlier, presumably colder, period during whith *Podocarpus* was more widely distributed than at present, i.e. are relict. The requisite cold conditions are known to have existed during the last glaciation, ending some 11,500 - 10,000 years ago (Colhoun 1978).

As with most podocarps, the fleshy bract supporting the female cone of *P. lawrencii* is likely to be attractive to birds and the seasonal migration of birds to and from the Central Highlands is a possible way podocarp seed has been carried to the Douglas River. This seed type may also be transported by water and the individual specimens growing downstream of the waterfalls on the Douglas River are probably spreading from the upstream stands in this way. Both *Celmisia* and *Gnaphalium* have florets with a pappus, making wind-dispersal of their seeds possible. In contrast *Cotula alpina* lacks a pappus and its seeds are unlikely to be dispersed far from the parent plant.

Accordingly it is possible that all 'highland' species except *Cotula alpina* have been independently and fortuitously established. Taken collectively, the evidence for fortuitous establishment becomes less likely and (circumstantially) five subalpine species in the one area supports a relict origin. A similar argument might be put forward for the presence of riparian rainforest scrub along the Douglas River. Testing this hypothesis will require a study of the vegetation history of the East Coast plateaux and gorges, e.g. via fossil pollen preserved in the river marshes. Pollen of *Podocarpus*, *Nothofagus cunninghamii* and *Atherosperma* is distinctive, making past *local* occurrences easy to detect via pollen analysis of cores taken from the river marsh deposits and dated by radiocarbon.

If *Popocarpus et al.* are in fact relict species on the Douglas River, then current theories on the distribution of some plant communities during the last glaciation and directions of spread in the postglacial will have to be revised. These propose that depressed temperatures and reduced effective precipitation had resulted in a substantial lowering of the treeline across Tasmania, leading to 'cold steppe' grasslands in inland

eastern Tasmania and restricting rainforest and conifer species mainly to western Tasmania in the latter part of the last glaciation (Macphail 1975, 1979; see also Ogden and Powell 1979).

Because conditions in eastern Tasmania were dry as well as cold, particularly during the "glacial maximum" some 18,000 years ago, any expansion of *Podocarpus et al.* to include the Douglas River is likely to have taken place somewhat earlier. Extremely wet, relatively cool conditions occurring earlier in the Last Glacial, at about 32,000 years ago, are one possibility. Survival of the relict community on the Douglas River, through the "glacial maximum" and subsequent postglacial period would only be possible in a deep gorge niche such as the Douglas River provides. As with the conifers and rainforest in "refugia" in western Tasmania, these relict communities would act as sources of seed enabling the plants to recolonize ice-influenced terrain during rapid rise in global temperatures between about 14,000 and 10,000 years old.

The discovery of *Podocarpus* and composites reported here illustrates the need for extensive plant collections in areas outside National Parks. Such information together with good habitat data assists in the understanding of the present-day ecology but is essential in the pollen-based study of past vegetation and climates. Here the modern altitudinal limits for important species are widely used to transform the fossil pollen data (reflecting changes in past vegetation) into palaeoclimatic values. Anomalies such as the Douglas River *Podocarpus* emphasise the dangers of an overly precise use of botanical data to deduce past environments, particularly by non-botanists. The New Zealand combination of modern plant distribution data (e.g. Burrows 1965) and fossil pollen data (Moar 1971, Dodson 1978), allowing patterns of postglacial plant migrations to be established, is a model of what might be achievable in Tasmania.

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JAMES MEEHAN'S SURVEY OF HOBART TOWN IN 1811

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(with two text figures)

ABSTRACT

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During his visit to Hobart Town in 1811, Governor Macquarie instructed Acting Surveyor James Meehan to make a design for the layout of this small but growing settlement on the shores of the Derwent River.

The field notes of Meehan's survey work executed as a result of these instructions were recently rediscovered and were analysed and plotted by the author, enabling him to show in map form his interpretation of these survey notes.

The resulting map portrays an interesting picture of Hobart Town during the Collins period which is not complete. This interpretation of Meehan's survey notes may encourage further studies.

JAMES MEEHAN'S SURVEY OF HOBART TOWN

After taking office in 1810 Governor Macquarie decided to make a personal inspection of Van Dieman's Land in general, and of Hobart Town in particular. He found on his arrival in Hobart (November 23rd, 1811) a collection of miserable huts interspersed with some structures built of brick, public buildings of an unsatisfactory quality, and a few muddy tracks and laneways, wandering at random across the hilly slopes, along several rivulets and the shores of Sullivans Cove. Obviously no building controls had been applied, no thought had been given to a desirable layout of the settlement with suitably located roads, and no areas of land had been set aside for any specified public purpose.

This situation alarmed Macquarie, as his experience as an administrator led him to see clearly the dangers of a repetition of the rather confused manner in which Sydney had grown up along the cart tracks leading out into the bush. Macquarie almost certainly discussed the matter first with the local officers and merchants, and then issued instructions to surveyor James Meehan (who had come with Macquarie as a member of his party) "...to frame and mark out a regular Plan..." for the settlement(1-see References).

The possible implications of these instructions put Meehan in a difficult position. The superimposition of a new grid system of streets over the existing random development of Hobart Town would inevitably mean that some people would retain all or much of their land and improvements while others would have to start all over again. It also meant that the grid system of streets had to be extended from a predetermined baseline which could be located almost at will in such a manner that the property owners along this line would profit very much indeed with little fear of the probable losses that less fortunate (or less influential) occupiers of land were likely to suffer. Meehan also had to take into account the topography of the settlement and its surroundings - deep gullies and steep slopes were everywhere. It must have taken quite some mental effort to stand in semi-cleared bushland, trying to visualise a smooth carriageway lined on both sides with prosperous houses and cottages.

The speed with which Meehan executed his instructions is impressive. Macquarie and his party arrived on Saturday, November 23rd and on the following Tuesday Meehan was already at work defining the all-important base line from which he was to extend his "... regular Plan..." There are no entries for the next two days, but no doubt many hurried consultations took place on the locations where the future cross roads (Argyle,

Elizabeth, Murray, Harrington Streets etc.) were to strike this base line street (now Macquarie Street). People such as Ingle, Murray, Birch and McAuley did very well from these discussions - there are references in Meehan's survey notes to stakes representing street corners, the locations of which were later slightly moved giving different dimensions to allotments which could now be sub-divided and sold. On the other hand, Meehan was also able to avoid the area where many tradesmen and small business people lived by locating the bush track leading to New Town (now Elizabeth Street) somewhat further to the northeast, thus necessitating the construction of a new bridge (Wellington Bridge, commenced in 1816).

It should also be noted that there are differences between the plan as approved by Macquarie and the city blocks as they are today. Although these differences are small (some blocks are slightly larger or smaller than originally indicated on the 1811 plan), they are in nearly all instances significant in that they tend to favour an application of common sense rather than the inflexible execution of an instruction.

On Friday 25th Meehan made a traverse survey encircling the small settlement (at the time counting about 1000 people in total), while on the following Saturday he again charted further details of development along his "New Street" baseline. On that same Saturday the major points of his work over the past few days were plotted on a sheet of cartridge paper, a tedious job, which according to the practice of that time, was very likely done by himself. The proposed streets then were superimposed on this plot, and the final drawing was finished with a coloured wash indicating building lines etc.

All this precise and painstaking work was even completed (in all probability in duplicate!) in time for Macquarie to scrawl his approval on the plan - at least, if we are to accept the date mentioned on the plan in his own handwriting!

The next day was a Sunday, but this did not prevent Macquarie from issuing the first town planning ordnance in Tasmania:

> "His Excellency the Governor, having observed with much regret, since his arrival here, that the several Public and Private Buildings in Hobart Town have hitherto been erected in a very irregular manner and without any plan whatever, has judged it expedient, and essentially necessary for the better appearance of the Town itself, and the accommodation of the Inhabitants, to frame and mark out a regular Plan for the future guidance and observance of all such Persons as may be permitted to reside and build in it. The Acting Surveyor has accordingly, by His Excellency's Direction, marked out with Stakes, in appropriate Places, the different divisions of the Town, which is for the present to consist of a large Square nearly in the Center of it, and Seven Streets, three of them running nearly parallel the whole length of the Town, and the remaining four crossing the three long Streets at right angles. The Governor has named the square George's Square, in honour of our most Gracious Sovereign, and has given the following names to the seven Streets, vizt. Liverpool, Collins and Macquarie are the names given to the three long Streets, Argyle, Elizabeth, Murray and Harrington being the names given to the four Cross Streets. Posts having Finger Boards, nailed on them, with the names of the Square and the several Streets, having been erected at their respective commencement and terminations to point the more accurately the direction of the Square and Streets, they are in future to be known and called by the names given to them. On the Square it is intended at some future period to erect a Church and Court House or Town Hall and a Main Guard. It is also intended that a Public Market, under proper regulations, shall be held in the center of it every Saturday, as soon as it can be ascertained whether the settlers are disposed to bring the Produce of their farms for sale to this weekly Public Market, the Square likewise as it consists of an extensive area, will answer for a Public Garrison Parade."(2).

This he followed up with a building ordnance, spelling out at the same time the conditions under which the settlers henceforward were permitted to receive and occupy land:

> "No person in future is to presume to build a House of any description in Hobart Town without previously submitting a Plan thereof to the Commandant, and receiving

his Sanction for erecting the same. Such persons as are able and willing to build Brick or Stone or weather boarded Houses, of two stories high, forty feet long by 16 feet broad in the Clear, tiled or Shingled and properly Glazed, will be entitled, on entering into security for erecting such a Building within two years, to receive a Town Allotment of 100 Feet in Front and 132 feet in depth, with 21 years Lease of the same from the Governor in Chief. Such persons as are not able to build two Story Houses but are willing and able to erect houses of one story high, thirty six feet long by 14 feet broad in the clear, tiled or Shingled and properly Glazed, on entering into security to erect the same within two years, shall be entitled to receive a Fourteen year Lease from the Governor in Chief of a Town Allotment consisting of sixty feet in front and 132 feet in depth."(3).

Macquarie then mentions Meehan's plan the ink of which was hardly dry:

"His Excellency the Governor has delivered a Plan of the Town, as now subdivided and laid out, to the Commandant for his own guidance and also for that of such Persons as may wish to receive Town Allotments and build Houses in Hobart Town and to this Plan such Persons are accordingly referred, it being His Excellency's positive Orders that the new Plan in question shall be rigidly adhered and conformed to in every respect."(4).

After briefly indicating his wish that a signal station was to be erected on Mount Nelson, Macquarie then obviously decided that he had raised enough dust for some time to come and closed his proclamation by saying that he was now

".....under the necessity of setting out for Port Dalrymple tomorrow, and is sorry he cannot at present prolong his stay at this Settlement; but he trusts he shall be able to visit it soon again, when he anticipates the pleasing hope of finding it greatly improved in every respect."(5).

In 1813 Meehan returned to Tasmania to solve many of the disputes and arguments which resulted from title descriptions made by earlier surveyors, which were not always clear. Meehan did a lot of work in Tasmania that year, and also enlarged and improved on his 1811 definition of the new streets in Hobart Town.

From his notes the gradual development of Davey, Barrack, Bathurst and Campbell Streets emerge. He also surveyed many new allotments of land made available to settlers as a result of Macquarie's proclamation of 1 December 1811 (see above). Other notes also contain some interesting sidelights on some of the problems he encountered during his surveying activities. Samples include:

(p. 87 - transcribed):

"... to Hanna Garrett: 139 along Murray Street to the corner of a new street, then 151 feet along that new street - this land to be in lieu of a house that is to be taken down".

(Note: this obviously was a straightforward case of compensation for a house located within the reservation for one of the new streets).

(p. 88 - transcribed):

"... from chainage 3.20 to 4.71½ an allotment to John Cenliff(?) who promises to build a two-storey brick house, and who will give securities to that effect".

(Note: a case of someone having applied for a block of land 100 x 132 feet to build on - see Macquarie's promises mentioned earlier).

Of course there were other cases:

(p. 73) "... making half an acre for Mich. Lee, on behalf of himself and others a Free Masons - having had that claim from Norfolk Island".

An entry on page 77 gives an interesting sidelight on the continuous arguments which Knopwood had with later administrators with regard to his land on Battery Point: "... to discover the quantity of land Mr. Knopwood supposes himself possessed of, which should be 50 acres."

By this time the new street layout of the Hobart of today was beginning to show itself. Much of the old Hobart Town from the Collins period was rapidly disappearing and indeed, during the periods of Lt. Governors Davey and Sorell (1812-1824) there are many

references in the official documents and newspapers to convict gangs constructing roads and bridges, and to some of the problems relating to people having to move to new allotments (often containing uncleared bushland) because of their earlier houses were in the way of a new street.

Very little of the Hobart Town of the Collins period survives. In fact the only known structure of that period still in existence is the Commissariat Store in Macquarie Street, recently adapted for use by the Tasmanian Museum and Art Gallery. Other remnants of this period may also still be in existence, but their recovery would almost certainly involve archaeological research.

There are a number of cadastral boundaries in central Hobart which either definitely or almost certainly date back to the Collins period. They include the SW boundary line of the Risby Brothers property in Collins Street (the old Government Garden), the rear boundary lines of the OBM bookshop and adjacent properties in Collins Street (an early street), the Elizabeth Street end of the Cat and Fiddle Lane (a track along the 'Town Creek'), a rectangular parcel of land behind the Commonwealth Bank in Elizabeth Street (a small paddock facing an early lane), and certain cadastral lines in the area behind the Theatre Royal which, in all probability relate to early grants or leases to Matthew Bowden and others in that area. Several property boundary lines between the AMP building and the City Hall in all probability originate from the bush track that was formed when Collins and his soldiers, convicts and settlers forced their way from the landing place behind the present Hope and Anchor Hotel in Macquarie Street through the dense scrub to an area between the present GPO building and Hadley's Hotel. Soon this track became a pathway, then a lane and by 1811 it started to take on the appearance of a street lined with little cottages surrounded by paling fences.

The map of early Hobart Town which accompanies this paper was based mainly on the information contained in the fieldnotes of the survey which Meehan did in 1811. Some supplementary detail however was taken from his 1813 survey, and use was also made of other documentary information dating from that period. However, great care was taken not to confuse the general situation portrayed by the map with information which is definitely of a later date. On the other hand, use was made of later material portraying a situation which, in all probability, also existed in 1811. This material included a survey of about 1826 of the southern shoreline of Sullivans Cove(6), Lee Archer's map of 1827(7), and Capt. Welch's 1827 survey of Sullivans Cove(8), from which the fathom lines were compiled.

The reconstruction of the map of the swampy environment at the mouth of the Hobart Rivulet posed great difficulties, but a careful study of Lands Department Charts Hobart 4, 5, 12 and 37 provided much information, and the configuration now shown on the map should be close to the truth.

The reconstruction of Hunter Island was an interesting exercise. Early surveyors (including Meehan) didn't survey it precisely, but in the 1820's a decision was made to take the gallows down, and subdivide the vacant space into allotments for warehouses. This subdivision found its way onto Lands Department Chart Hobart 12, and later again onto Hobart 37, and together with other supplementary information made it possible to redefine the outline of the island, because this subdivision can still be found back on the ground. Of the warehouses of that period however some, like Hunter Street Number 33, still exist: they date from about 1827(9).

Meehan's survey work in the area of the old Hobart Railway Station and Gasworks contains a number of bearings which cannot be reconciled with modern information and as a result the detail shown on the map around the lower end of Campbell Street may have to be slightly revised - if more exact information is ever discovered. Fortunately, Meehan picked up some cadastral detail near the area of the railway roundabout which survived for many decades and found its way onto other title surveys(10) which could be related to the situation of today. As a result much of his work in this area could be salvaged and used

For a modern basemap of the centre of Hobart, use was made of maps 5172-24 and 5171-4 as published by the Southern Metropolitan Planning Authority. Their accuracy and wealth of detail were ideal for this purpose, providing many clues and 'hidden' information about early Hobart Town which otherwise would not have been apparent.

Notwithstanding all this it is recognised that the reconstruction of early Hobart Town as now presented is by no means complete.

MAULT'S MAP OF EARLY HOBART TOWN

The next item of interest is a reconstruction of Collin's Hobart Town made by A. Mault in the late 1880's. This map accompanied J. Backhouse Walker's well-known papers on the settlement of Risdon Cove and Hobart Town, and was compiled by Mault from a chart of the Hobart settlement produced by G.P. Harris during the winter of 1804, a copy of Meehan's map of Hobart Town in 1811, and a (then) modern map of Hobart c. 1885.

Of these maps, the Harris map cannot be traced. It is not chart Hobart 10 (also by Harris), now in the files of the Lands Department in Hobart. The reference shown on Mault's map to Meehan's survey plot states that it was taken from "... a plan inscribed 'plan of Hobart Town' approved L. Macquarie, Hobart Town, 30th November 1811. Transmitted to the Surveyor-General in C.S.L. 44/413 of 10th December".

This last sentence does not occur on Chart Hobart 1 as held in the Lands Department, nor do many of the cadastral and topographical details of Mault's version of Meehan's map appear on this chart and it is clear that Mault must have had access to a more detailed version of Meehan's survey. This impression is further strengthened by the fact that chart Hobart 1 in the Lands Department is accompanied by a photocopy of a more detailed version of chart Hobart 1, this photocopy (a) depicting a drawing obviously dating from around the turn of the century, and (b) showing information which required access to Meehan's survey results of 1811.

There remain however a few minute but possibly significant differences betweee Meehan's survey notes, Mault's copy of the chart in the Lands Department(12) and Mault's map in the Walker Memorial Volume which cannot be explained with the information on hand. Fortunately, they are indeed minute.

Comparing the handwriting and other detail of this photocopy with Mault's map in 'Early Tasmania' it would seem quite probable that Mault is the author of the map shown on the photocopy and that he therefore would have had access to the more detailed chart of Hobart Town prepared by Meehan in 1811. This chart has not yet been found: if it still exists it may surface one day in Sydney or in London.

In view of the above, it seems therefore reasonable to conclude that

a. Meehan prepared (at least) two manuscript charts of the results of his 1811 survey. Chart number one gave a detailed account of the major features of Hobart Town at that time; it was signed by Macquarie on November 30, 1811 and was sent to the Survey-General in Sydney in December (Mault refers to this correspondence as Col. Secr.'s letter of 44/813 of 10th December" - so far, it has been impossible to relate this reference to any known documents).
   Chart number two is the one now held in the Lands Department, Hobart(13). It is a simplified version of the first one and was handed over by Macquarie to Major Geils on December 1st, 1811(14) for his use and guidance.
b. Mault managed to obtain a tracing of the copy that was sent to Sydney in 1811. He then made a fair-copy of this tracing after having transferred the main points by pricking them through the tracing onto heavier paper with a pin (these pinpricks clearly show on the photocopy). This fair-copy also has not been found, but the photocopy of this drawing now accompanies chart Hobart 1 in the Lands Department. The very existence of the photocopy means that Mault's fairdrawing was still in existence three or four decades ago and also that if this fair drawing still exists, it is more likely to be still in Hobart than anywhere else.

c. Mault did not have access to or did not bother to analyse Meehan's survey field notes, at that time held in the Lands Department in Sydney. Mault was a very experienced and painstakingly precise maker of detailed engineering survey charts of Hobart around 1890 and certainly would have picked up a few small discrepancies in Meehan's own manuscripts.

Once the situation was understood to be most likely as outlined above the 'Mault Map' became a great help in the interpretation of some of Meehan's more obscure passages. Because of this it is believed that the reconstruction of Meehan's 1811 survey of Hobart Town as now presented is as accurate as his survey observations allow it to be and that any minor errors which may have found their way into the compilation will indeed be minor and will not invalidate the general impression now given by the map.

MEEHAN'S SURVEYING METHODS AND FIELD NOTES

Meehan worked with a very simple form of theodolite, perhaps the one mentioned in one of Governor King's letters to Collins in 1805(15). This instrument was in fact no more than a compass with a sighting arrangement which revolved around an edge or scale divided into 360 degrees, mounted on a tripod. Distances were measured in chains and links while the direction of each line was expressed in a compass bearing down to one half (or sometimes a third) of a degree. The accuracy of such an instrument and working method is not very great and one also has to trust and pray that the convicts working as chainmen for Meehan kept their iron axes and other tools at an appropriate distance from the compass! For these reasons, the bearings of his lines remain the weakest spot in Meehan's work, making it at times very difficult indeed to produce a credible graphic plot of his survey notes. Notwithstanding all these technical problems (compounded by the environment in which he had to work), Meehan was able to deliver quite accurate work most of the time.

Meehan's notebooks were made from a large sheet of paper folded over several times to finish up with a paper size of about 95 x 150 mm. The centre-fold would then be hand-stitched into a piece of soft folded leather after which the sides were cut open with a knife. Meehan usually wrote on the righthand pages only and at the end of the pages simply turned around and started again. There are, however, the occasional entries on odd pages which defy all attempts to link their information with material from other pages. Meehan was one of the last surveyors to use the already outmoded 18th century system of abbreviated notes in longhand and a typical example would be:

(13.7)	N11½E 530	bank L. at 3 is .50L
(13.8)	N6½ W 299	cor of Loanes Garden
(13.9)	edge of bank -	at 1.beach, 40L
(13.10)	bottom S16W -	Side up $10^2/3N$

In this example the details of the bearings and distances are quite clear but the method used to indicate the rest of the detail along the traverse often causes major problems. The numbers at the start of each line are modern references. With the permission and co-operation of the State Archives, each page of the notebook was numbered and the above quotations can therefore be found on page 13, lines 7 to 10 of his 1811 notebook This method of referencing Meehan's information has proved to be very convenient and helpful, especially during the compilation stages of the graphic plot. There are quite a few of Meehan's fieldbooks still in existence and the Tasmanian State Archives is at present allotting reference numbers to each book.

OTHER HISTORIC MATERIAL FROM MEEHAN'S SURVEY NOTES

Meehan's survey books also contain many references to people and structures of historical significance.

He refers several times for instance to an 'orphan house' and an 'orphan school' (probably one and the same building) at an unfortunately imprecise location near Antill Street. This reference is of great interest, as the existence in Hobart of such an institution as early as 1811 was only vaguely known previously. Other remarks relate to early mills on the Hobart Rivulet (including the one of Mr. Nash), and to a bridge located

in front of today's Kodak shop in Elizabeth Street. The location of the powder magazine on the edge of Sullivan's Cove is also shown but subsequent development of the site makes it unlikely that remnants will ever come to light.

The implications of some of the measurements noted down in Meehan's notebook are also interesting. The size of the Government House at that time (located between the modern Franklin Square and the Town Hall) was a miserable 18.5 m wide by 5.43 m deep - hardly enough for four or five small rooms and a narrow passage! The timber church erected over Collin's grave was reputed to be small, and so it proved to be in Meehan's notebook; it measured only 15.3 x 6.2 m. It also was probably built rather poorly, because 18 months later he notes (in his 1813 surveys) that the church is no longer there. Finally the position of the most important place in the settlement was noted: the flagstaff from which the Union Jack signalled the presence of British sovereignty on this island. In front of this flag Collins used to hold an occasional parade or ceremony, or would read the riot act to that group of Hobart's population who appeared to be in need of such action. Nowadays this spot lies quietly and forgotten underneath the Lord Mayor's reception room in the Hobart Town Hall.

Meehan never hesitated to mention names; especially in his 1813 notebooks a large number of the early inhabitants of Hobart Town get a mention and a further future study of these names should enlarge our knowledge of the pioneers of that period quite considerably.

When in 1813 Meehan surveyed the sandy beach near the 'Government Store' he picked up the "... tree marked in January 1804." (58.5). This is a very significant remark because of its implications. Meehan spent several months in the Derwent region late in 1803 and early 1804 using Risdon Cove as his base while exploring the surrounding countryside, charting topographical details and making general observations as he went along. Chart Monmouth 0 in the Lands Department indicates that one of these excursions went along the mouth of the Hobart Rivulet but Meehan's fieldnotes of this traverse so far have not turned up. The above comment in his notebook indicates however that this visit occurred in January 1804, a few weeks before Collins arrived from Port Phillip with his expedition. The time between the two events is long enough for Meehan's opinion of the environment of the Hobart Rivulet to have become known to the inhabitants of Risdon Cove and almost certainly they would have passed these views on to the settlers of Collins advance party who arrived at Risdon early in February and a few days before Collins himself arrived in the 'Ocean'. It is therefore highly likely that it was based on the intelligence of James Meehan that Collins and his party on their exploratory trip of February 17, 1804, went straight to Sullivans Cove, returning that evening to Risdon Cove "... much delighted..." with the decision of "... having pitched on a place about five miles lower down the river" (16).

Nowadays the location of the tree is underneath the pavement near the southernmost corner of the City Hall.

AN ANALYSIS OF THE LOCATION OF MEEHAN'S STREETS

Because of the very short time available to Meehan during his 1811 visit the 'setting out of the streets of Hobart Town' can not have been more than the placing of a few stakes in the ground, while much of this ground would have been still covered with (burnt?) timber, scrub or rough paddocks.

In Macquarie's proclamation of 1.12.1811(17) he mentioned three 'long' streets (Macquarie, Collins and Liverpool) and four 'cross' streets (Argyle, Elizabeth, Murray and Harrington), while Franklin Square was called George's Square. Davey Street is shown but not named, although on the copy of Meehan's plan which was sent to Sydney it may have been called Pitt Street. The pegging out of Davey Street however was not done till Meehan returned to Hobart in 1813, when he also pegged out the alignments of the other streets which nowadays make up Macquarie's 'regular plan': Molle, Barrack and Campbell Streets and the streets north of and parallel with Liverpool Street.

We need to visualise a series of stakes standing forlorn somewhere in the bush

(especially north of Liverpool and west of Harrington Street) and it was not until the period of Lt. Governor Davey and Lt. Governor Sorell that the gangs of chain-legged convicts began to clear the spaces between these stakes and to cover them with crushed sandstone rubble.

The streets in the centre of Hobart by then had been surfaced in some rough-and-ready manner, especially where these roads left the sandstone of the higher ridges; the bitumen of the intersection of Elizabeth and Collins Street for instance is only a few centimetres thick and is resting directly on solid sandstone. Where however these streets were near creeks use was made of the boulders and smaller pieces of stone in the creek bed to provide a firm surface underfoot - recent excavations in the middle of the Mall in Elizabeth Street confirmed just that, precisely 0.9 m underneath the present pavement surface.

There are no known references to the exact reasons which led to the location of the first seven streets as shown by Meehan on his 1811 plan(18). A close study however of the topographical problems which he faced, together with the complications of the existing development (some of which obviously had to be retained) make it quite probable that the following main considerations influenced his decisions very much:

a) Many of the senior officers and merchants had their interests located on the ridge between the Hobart Rivulet and Sullivans Cove and any decision concerning the 'base line street' (Meehan called it the 'New Street') was bound to take into account the long-term interest of these people.

b) Collins' Government House was located between the north-eastern boundary of Franklin Square and the south-western entrance of the Town Hall and it becomes obvious that somebody wanted to capitalise on this location: the 'Great Route to the North' (i.e. along the River Derwent into the inland) had to start — and end of course — in front of the steps of Government House.

c) Other important considerations were the retention of easy access to a mill in Liverpool Street, access to the paddocks of what is now the Domain and the location of and access to the Commissariat Store (opposite the Prince of Wales Theatre).

Macquarie Street: With the above matters in mind Meehan first surveyed his base line, later to become the N.W. side of Macquarie Street. In fact, one gets the impression from his survey notes that there may already have been plans for a street in this location and orientation: the fact that the rear of the Commissariat Store (215° 45') is virtually parallel with his baseline (214° 30') was noted, together with the fact that the orientation of the store, the width of the future Macquarie Street (100 feet at that point) and the orientation of his Macquarie Street baseline are obviously priority number one on page one of his survey notes. The orientation of his base line was approximately southwest; an orientation further to the south would have made the street too steep near the Anglesea Barracks, while only a fraction more to the west would have led the street into the Hobart Rivulet near the present Molle Street Bridge. Although the baseline went through several parcels of land allocated to various people (including Ingle and Birch), nobody objected as in this manner much land became available for subdivision.

Elizabeth Street: After the baseline from which a rectangular street pattern was to be extended had been defined on the ground by means of a number of stakes, a few days passed — no doubt to give the interested parties an opportunity to consider the implications of the new situation and to await Macquarie's personal approval after his return from a two-day excursion to the New Norfolk area. This approval must have been readily given, because early on the following day we find Meehan surveying a traverse around the small settlement, in the course of which he picks up the intersection of the early Elizabeth Street and a laneway (now Liverpool Street) in which the mill of Lt. Lord and Mr Collins stood — now the area of the Ellison Hawker bookstore in that street.

A new street leaving Government House at right angles to Macquarie Street would run into serious contour problems all the way from its crossing of the Rivulet near the Hospital to the top of Trinity Hill, but would also be at an angle with the front of Government House, an aspect which undoubtedly would have been considered undesirable.

A further complication was the fact that there already was a vaguely curved road or track, leading from the north-western corner opposite the G.P.O. via the Elizabeth-Collins Street intersection to near the intersection with Liverpool Street. To avoid a major disturbance of the development already there Meehan commenced his centreline of what was to become Elizabeth Street from the steps of Government House (a spot nowadays covered by a parking strip for motorcycles), but directed this line halfway between the existing bridge across the Rivulet (a spot now covered by the Venture Store) and a dogleg bend in the Rivulet next to the National Bank opposite the Venture Store. Luck was with Meehan - his new location of Elizabeth Street finished up nicely on the easier gradients of the western slopes of Trinity Hill.

This location in effect pushed the centreline of Elizabeth Street away from the steps of Government House and to compensate for that, Meehan retained the southwestern boundary of the existing roadway along the Elizabeth Street frontage of the Colonial Mutual building, thus producing a widening of this street near the G.P.O. which still exists. (This early road curving its way from Government House to the bridge across the Rivulet had its origin in the footpath through the bush from the area around the Governor's tent to the flat banks in a bend of the Hobart Rivulet, along which the convict water bearers carried their drinking water which they had scooped out of the rivulet between manferns and tall rising gumtrees...)(19).

Harrington Street: Meehan's baseline (along the northwestern boundary of Macquarie Street) went through Birch's land at right angles, and where it crossed the 'backfence' of Birch (all of 1500 feet removed from the turmoil of Government House!) it seemed a good place for one of Macquarie's cross streets. As much of the land involved was still either virgin bush or semi-cleared land there was no need for this street to be anything else but at right angles to Macquarie Street. This street became Harrington Street. Other streets further to the southwest (Barrack and Molle Streets) were simply orientated parallel with Harrington Street when Meehan staked them out in 1813. Because however of the increasingly steep slope on the northern side of the rivulet, Molle Street was the last major street in that direction.

Murray Street: In Meehan's survey notes a fence described as 'Capt. Murray's Fence' ran along the present southwestern side of Murray Street from Macquarie Street to a tree on the bank of the Hobart Rivulet, a spot nowadays right underneath the Murray Street entrance of the Centrepoint shopping complex. It is not known on which side of the fence Murray's land was located, if indeed it was Murray's private land at all. Capt. Murray at that time was the Commandant of Hobart Town and Meehan may well have meant a rectangular area of land which most likely was located on the southwestern side of 'Murray's Fence', and on which for very many years the military were located (now the area of Hadley's Hotel).

It is however obvious that 'Murray's Fence' was a significant landmark and significant enough to determine the direction which Murray Street was to take; this is supported by the fact that the projection of Murray Street towards Sullivans Cove was determined at a later stage in an almost offhand manner — straight through Sgt. McAuley's house and property! (now the site of the Savings Bank of Tasmania). At the northwestern end of Murray Street, steeply increasing slope prevented a continuation much beyond its intersections with Warwick Street, causing many headaches for surveyors in the 1820's and 30's.

Argyle Street: This street caused some problems for Meehan and it is clear from his survey notes that he moved the location of his corner stakes on the Macquarie Street baseline several times before he was satisfied. The reason for this is not quite clear; it may be that he simply had some problems in lining his stakes up, while for some as yet unexplained reason the northeastern corner of the Argyle - Liverpool Street intersection apparently also became a 'fixed' point. One thing however soon becomes very clear indeed: the street went straight through the middle of Ingle's land, thus creating valuable frontage for Ingle which was suitable for subdivision.

The intersection of Argyle Street with Macquarie Street produced two very valuable

corner blocks superbly located, being close to Government House, the Commissariat Store, the Landing Place (between the City Hall and the Hope and Anchor Hotel) and the Guard House. It is therefore not surprising that Ingle chose one of these two corner blocks to build on (Ingle Hall - 1814), while Norfolk Island settler James Mitchell built a mirror image of Ingle Hall (in 1814 or 1815) worth £2,500 on the opposite corner block - a clever act of civic planning which no doubt aimed to copy the better type of development that went on in London at that time. Many remnants of Mitchell's house are still in existence, but nowadays hide behind the added modern facade of the Hobart (Town) Hotel (of which the licence incidentally is one of the older ones in Hobart).

The gradients of the lower half of Argyle Street were almost better than those of Elizabeth Street, but Elizabeth Street and the track from its northern end through the forest to New Town had the advantage of already having been in use for several years. Argyle Street on the other hand still had to be constructed and in the end lost its battle for prominence with Elizabeth Street because its northern end finished abruptly on the steep slopes below Stoke Street. Campbell Street was to suffer similar problems later on, requiring much public expenditure in later years to put things right.

Liverpool Street: The location of this street was the least difficult as its location was largely controlled by the mill of Lord and Collins(20). This mill was located on or close to the present site of Ellison Hawker's bookstore in Liverpool Street (near the rear of the premises), and a road or laneway providing access to the mill (and other houses nearby) followed the bank of the Rivulet. Meehan probably was either told or decided for himself not to change this particular situation, while his traverse around the settlement would also have made it clear that he did not have much choice: the southwestern end of the street would either go straight up a steep hill (as later on Goulburn Street and Forest Road did), or the street would disappear into the Hobart Rivulet halfway between Harrington and Barrack Streets (a street which he added in 1813). Probably for these reasons the orientation of Liverpool Street differs from that of Macquarie Street. In 1813 Meehan linked the Argyle Street intersection of Liverpool Street with the already existing crossing of the Park Street Rivulet, another fixed point, causing a further deviation in the alignment of Liverpool Street.

Northwest of Liverpool Street, however, there was little or no development other than a few paddocks and for this reason the 1813 streets — Bathurst, Melville, Brisbane, Patrick and Warwick — are parallel to Macquarie Street - exactly as instructed by Macquarie. For the same reason Molle, Barrack and Campbell Streets (dating from 1813) are at right angles to Macquarie Street.

Collins Street: It is not clear why Collins Street is almost but not quite parallel to Macquarie Street. The northeastern end of the alignment had to stay away from the high sandstone cliffs along the Rivulet below the hospital, but also had to avoid a number of houses on the northern side of a lane or street which ran from near the AMP Building to near Hadley's Hotel. By departing from parallelism Meehan avoided major problems for th occupiers, although many of them lost their backyard which became Collins Street - the Collins Street premises of the OBM bookstore for instance is one of the sites the rear boundary line of which is still part of the northwestern side of this lane or street. (It is reasonable to suggest that this lane or street was the direct route between the landin place behind the Hope and Anchor Hotel and the military camp near what is now Hadley's Hotel. When however Macquarie Street was created there was no need to continue the existence of this lane and it was therefore abandoned by Macquarie and Meehan). At the western end of Collins Street there was no development to worry about other than a few gardens, and one gets the impression that here Meehan simply halved the distance between Liverpool Street and Macquarie Street.

George's Square (now Franklin Square): The original 1811 concept of the Village Square and parade ground underwent substantial changes during the course of the 19th century.

At first this area was developed as a garden surrounding Government House right from Argyle Street through to Murray Street and between Macquarie Street and the water's edge.

In the early 1820's however the Murray Street frontage of this garden (that is: virtually out of sight of Government House) was set aside for public purpose, after which a court house was built in 1823 on the corner with Macquarie Street. In later years more Government Offices were built on this strip of land.

Government House was not demolished until the late '50's, an event which was accompanied by a general reorganisation of the area. Elizabeth Street was extended as far as the harbour's edge, while Davey Street was finally extended through to Elizabeth Street - not along the easier contours as suggested by Meehan in 1811 (and being the location of an old track leading from Government House to Knopwood's Cottage Green) but in a straight line from Murray Street through to Victoria Dock.

Argyle Street was also extended from Macquarie Street to the waterfront and the ratepayers of Hobart thus obtained a new city block on which to build one of the finest Town Halls in Australia - 1866. What remained of the original idea of a Village Square was then again cut up: the western part was reserved for extensions to the Government Offices in Murray Street (this site is now occupied by the Premier's Department and the Court Buildings), while the eastern section was landscaped and re-named Franklin Square.

MACQUARIE'S BUILDING REGULATIONS

During the first few years after 1804 the early settlers used whatever building materials they could find and many of these materials came from the resources of their environment.

With so much timber on hand, split planks and palings were soon used for almost everything and most of the common building methods of rural Tasmania in the mid-80's were formulated in the early days of the colony. Meehan referred already in 1811 to paling fences, and also noted that the decking of the bridge across the Hobart Rivulet consisted of 'planking': solid slabs of timber, a construction method still used in the country today. Planking was also used for (often vertical) weatherboards and for interior lining, thin shingles for the roof. Those with more money to spend would use bricks instead of rubble or boulders for the fireplace, while the next step 'up' would be to build the front elevation out of bricks. Buildings entirely built of bricks or stone were notable landmarks in any street and the owners of such houses would have been very rich indeed compared with the rest of the population. If we add to this a generally poor standard of housing, the poorly constructed 'roads' (often no more than muddy tracks) and a generally unhygienic sanitary situation which favoured rats and other vermin, one can well imagine the horror with which Macquarie observed the existing situation in Hobart. Obviously, nothing worthwhile had been done to improve general housing standards, no land had been set aside for public building and amenities, most houses were too small and too close together and no thought had been given to an orderly development of Hobart Town either for that time or later.

Seen in this light the measures which Macquarie took were not dictatorial but very sensible indeed. In order to get the individual homes further apart he specified minimum widths of allotments - 60 or 100 feet, while all allotments had to be 132 feet deep, thus permitting each household to grow its own vegetables and to dispose of its nightsoil within its own boundaries. For an orderly placing of these allotments streets were needed and the frontages created by Meehan's formal streets would allow the subdivision of many of the required blocks of land. All streets were to be 60 feet wide, with footpaths 8 feet wide set aside for pedestrians. In addition, buildings had to be set back 20 feet from the street, thus creating a 100 feet minimum width between street facades. This last ruling was adhered to for quite a number of years and is the reason why such buildings as Ingle Hall still enjoy a garden in the middle of the city. In later years the authorities relaxed this requirement, especially in the city centre and many merchants used this space for a shop or other premises. As a result, many of the older Hobart buildings can still be recognised by a careful study of their construction behind their street frontage.

The 100 feet rule also had another purpose "... in this plan the houses are intended

to be 100 feet apart in the lines and the reason of intersecting the streets acutely is not to intefere with many houses which are now erected and which, if disposed of in a regular plan, must be entirely destroyed"(21). The problems of hardship that confronted Meehan when he had to decide where to locate the new streets have already been referred to earlier, and the 20-feet setback created a convenient margin which the authorities could use in difficult cases.

This they did and although the documents from the Davey and Sorell periods are full of cases in which people had to give up their house because it was located in the way of advancing convict road gangs, there are other cases where buildings lingered on for quite some years. Lands Department Chart Hobart 5 of about 1829 shows a number of such buildings (a notable case is in Bathurst Street between Argyle and Campbell Streets), and even Calder's survey notes of 1834 chart a number of cases which could possibly relate to 1811 or earlier.

REFERENCES

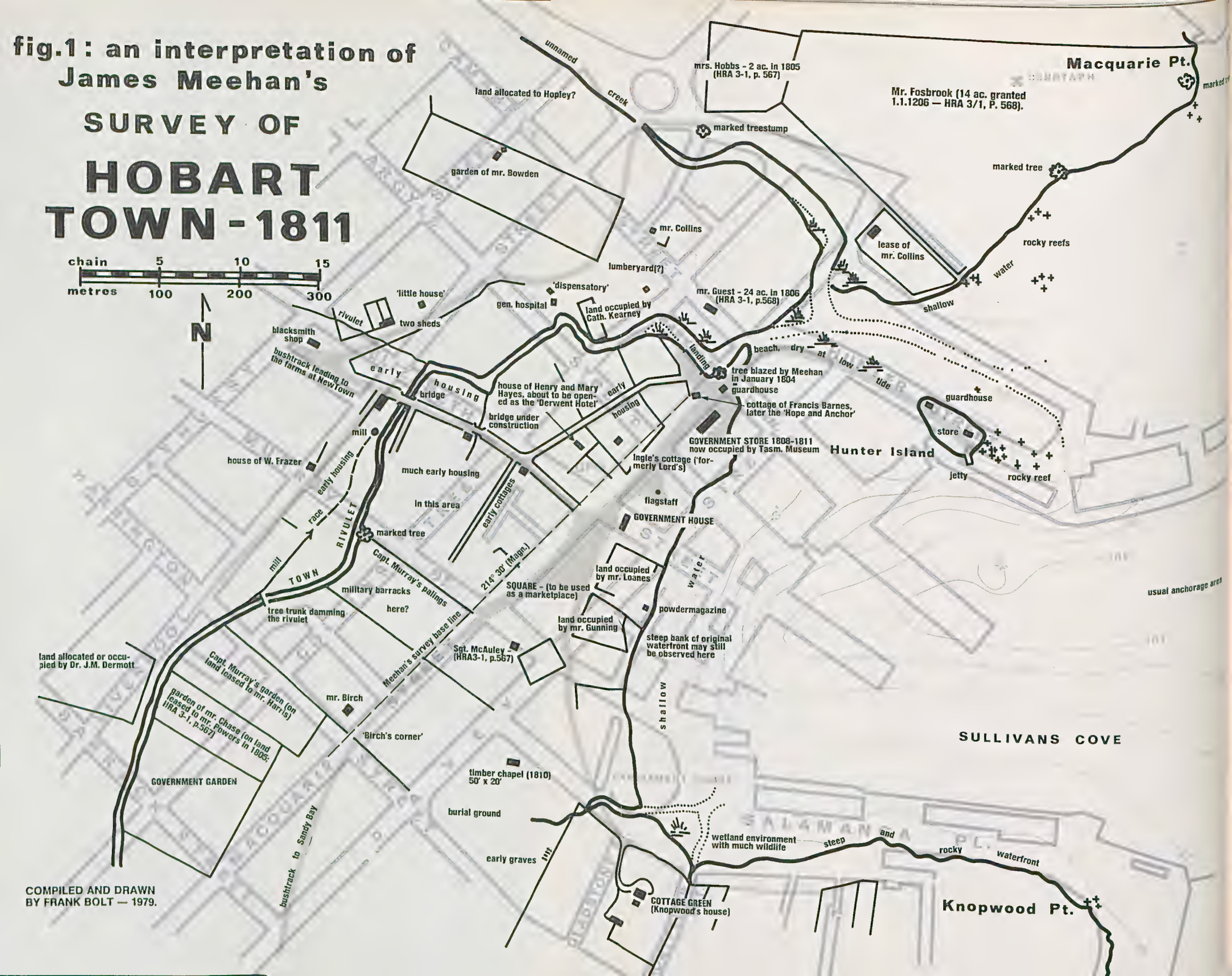
The interpretation in this paper and in the accompanying map of Meehan's survey notes of 1811-1813 is entirely my own. There are no known documents to 'prove' any of the conclusions that have been reached in this paper. These conclusions are reasonable in the light of the evidence available and with this evidence in hand it would be difficult to think of significantly different explanations of the way in which Meehan laid down the street pattern of central Hobart.

The detail shown on the map is not complete, but it is hoped that it will encourage others with other background knowledge to add to it in years to come.

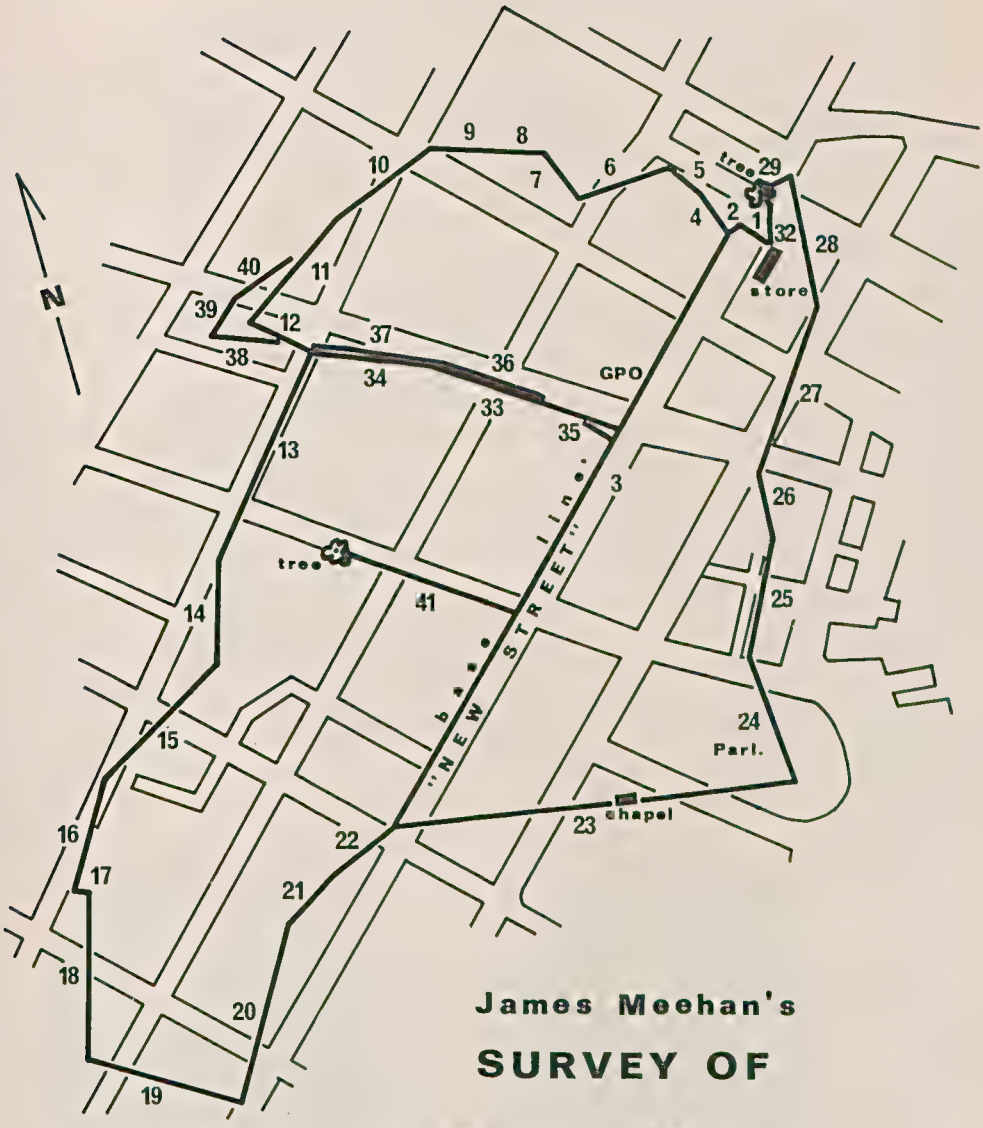
The main sources of information were Meehan's survey notebooks of 1811 and 1813(22), the various charts in the Lands Department of early Hobart Town (including those quoted in the text), and a large number of early title surveys in central Hobart now filed in the Lands Department.

1 — HRA 3-1, p. 512.
2 — ditto.
3 — HRA 3-1, p. 512 + 513.
4 — HRS 3-1, p. 513.
5 — ditto.
6 — Lands Department Chart Hobart 11.
7 — Lands Department Chart MPD 117/3.
8 — Lands Department Chart Hobart 16.
9 — Lands Department Chart 6, 12 + 37.
10 — Lands Department Surveys Hobart 6/15, 4/83 etc.
11 — Walker Mem. Volume 'Early Tasmania' - Government Printer, Hobart
12 — Lands Department Chart Hobart 1.
13 — ditto.
14 — HRA 3-1, p. 513.
15 — HRA 3-1, p. 302.
16 — Knopwood 17.2.04; HRA 301 p. 148.
17 — HRA 3-1, p. 512.
18 — Lands Department Chart Hobart .
19 — Hopton J.P.: John Pascoe Franklin; *Vict. Hist. Mag.* 30 (1960): p. 41.
20 — HRA 1-7, p. 129.
21 — Lands Department Chart Hobart 1.
22 — State Archives, Hobart.

fig.1: an interpretation of James Meehan's SURVEY OF HOBART TOWN - 1811



COMPILED AND DRAWN BY FRANK BOLT — 1979.



James Meehan's

SURVEY OF

HOBART TOWN - 1811

details of the central main traverses

fig. 2

APPENDIX

JAMES MEEHAN'S SURVEY OF HOBART TOWN (see fig. 2)

As an example of Meehan's survey methods, this diagram shows the survey traverse encircling the settled area of early Hobart Town, an area now covered by Central Hobart.

In view of the primitive equipment used by Meehan the outer traverse and its link with line 3 (the survey baseline along Macquarie Street) closes with a surprising degree of accuracy.

Note how the location of the traverse along an early traffic way (lines 33 and 34) differs from today's location of Elizabeth Street. This traverse however does not quite meet the junction of lines 12 and 13, although in all probability it did as measured by Meehan.

Line 29 terminated on a small beach near a tree which had been blazed by Meehan in January 1804, thus making it the first survey benchmark in Hobart.

Line 1 and Line 32 connected with the northern corner of the 'provision' (Government) Store. When Meehan made his survey in November 1811 this building had only just been completed. It is still in existence in Macquarie Street opposite the Prince-of-Wales Theatre; it now serves as an office for the Tasmanian Museum and Art Gallery.

Line 41 (along Murray Street) was in all probability the front fence of the early military barracks area, while the tree at the end of this line stood on the bank of the Hobart Rivulet - a spot now covered by the entrance of the Centrepoint complex.

Line 23 was orientated in such a way that it went alongside a small chapel over Collins' grave; the fieldnotes of this line are detailed enough to attempt the re-establishment of the exact location of this first chapel or church in Tasmania. Another interesting aspect of this line is that at that time it was apparently still possible to see from St. Josephs Church in Macquarie Street to a spot in front of Parliament House!

Meehan gives the following details about the traverses as shown on the adjoining page. For convenience of reference, they have been numbered here from 1 through to 41:

1	3.8	W40.5N	147	15	11.10	W41.75S	700	29	13.17	W23.5S	149
2	3.9	W25.5S	49	16	11.11	S20.33W	519	30	14.3	S32.75E	90
3	3.11	S34.5W	3066	17	11.16	E15S	65	31	3.6	N34.75E	46
4	8.5	N31.75W	215	18	11.18	S16W	753	32	3.4	N 1.75+E	142
5	8.15	W43.5N	186	19	21.1	E21.5S	703	33	20.3	W23.5N	900
6	9.1	W14.25	430	20	12.4	N20E	833	34	20.7	W11N	510
7	9.6	N32.5W	249	21	12.8	E43.33N	286	35	5.11	W36N	400
8	9.16	W 7.75	181	22	12.14	E33N	360	36	5.12	W21N	450
9	10.5	W 6.5N	319	23	12.15	E1.5N	1800	37	6.4	W14.25N	427
10	10.8	W33S	524	24	13.4	N14.67W	598	38	6.7	W11.75N	584
11	10.11	S44.33	620	25	13.7	N16.5E	530	39	7.1	N37.5E	202
12	10.12	E29.5+S	310	26	13.8	N6.5W	299	40	7.3	E30N	303
13	10.16	S28.33W	1005	27	13.11	N24E	800				
14	11.6	S 7.75W	500	28	13.12	N6.67Q	600	41	16.9	W24N	850

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(ms. received 14.7.1980)

A LATE MIDDLE CAMBRIAN DAMESELLID TRILOBITE CRANIDIUM FROM BEACONSFIELD, TASMANIA

by J.B. Jago
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(with one plate)

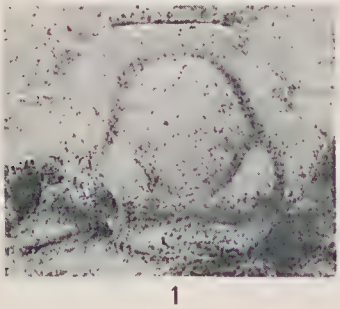
ABSTRACT

JAGO, J.B., 1981 (30 ix): A Late Middle Cambrian damesellid trilobite cranidium from Beaconsfield, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 19-20 (with one plate). ISSN 0080-4703. School of Applied Geology, South Australian Institute of Technology, Ingle Farm, South Australia.

A recent discovery confirms the presence of damesellid trilobites in a late Middle Cambrian fauna from near Beaconsfield.

Jago (1980) illustrated and briefly discussed a poorly-preserved late Middle Cambrian fauna from near Beaconsfield, which was discovered by Green (1959). In February 1980, Professor D. Green, Dr M.R. Banks and a party of geology students from the University of Tasmania collected further fossils from this locality. The fossils include the best preserved specimen (Plate 1, figs. 1 and 2) so far found at this locality. It is a substantially complete trilobite cranidium of a member of the Damesellidae; both the internal and external moulds are available. Of the specimens figured in Jago (1980) the cranidium figured in pl. 1, fig. 17 and the pygidium figured in pl. 1, fig. 21 probably belong in the same species as the newly discovered cranidium. As far as can be determined, the Beaconsfield specimens probably belong in a new genus of the Damesellidae, which is characterized by a substantial spine emerging from the posterior margin of the occipital ring and a glabella, with a broadly rounded anterior, which stops well short of the anterior margin of the cranidium. However, the preservation is not adequate to warrant formal description of the material and the erection of either a new species or a new genus.

The catalogue numbers refer to the collection of the Geology Department, University of Tasmania.



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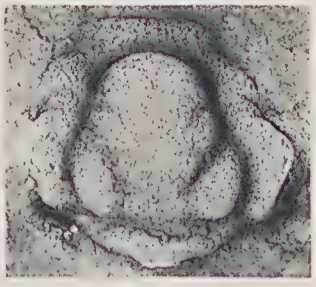

2

FIG.1.- UT 121077a, internal mould of damesellid cranidium, x 2.5.
FIG.2.- UT 121077b, rubber cast of external mould of damesellid cranidium, x 2.5.
Both specimens were whitened with magnesium oxide prior to photography.

ACKNOWLEDGEMENTS

Dr M.R. Banks and Mrs P. Green (University of Tasmania) kindly forwarded the latest collection to Adelaide. This work was supported by a grant from the Australian Research Grants Committee (E78/15078).

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Jago, J.B., 1980: Late Middle Cambrian fossils from Beaconsfield, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 114: 219-233.

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(ms. received 21.4.1980)

STRATIGRAPHIC TERMINOLOGY OF LOW-GRADE METAMORPHOSED ROCKS AT BATHURST HARBOUR, S.W. TASMANIA

by P.R. Williams
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(with one table and two text-figures)

ABSTRACT

WILLIAMS, P.R., 1981 (30 ix): Stratigraphic terminology of low-grade metamorphosed rocks at Bathurst Harbour, S.W. Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 21-28 (with two figures). ISSN 0080-4703. Department of Mines, Hobart, Tasmania, Australia.

A sequence of low-grade metamorphosed rocks surrounding Bathurst Narrows and Joe Page Bay in southwestern Tasmania crops out between areas of higher-grade metamorphic rocks. The higher-grade rocks have undergone at least two deformation events which did not affect the lower-grade rocks and are inferred to be the older of the two sequences. The lower-grade rocks are divided into five formations with conformable boundaries between them. These formations together form the Clytie Cove Group. A correlate of the Clytie Cove Group occurs ten kilometres to the east of the type section of the Group, which is around Bathurst Narrows and Joe Page Bay. Previously proposed correlations of the Clytie Cove Group with rocks in the Davey River area and on the West Coast Range are invalid, as they were based on an incorrect and incomplete stratigraphic section at Bathurst Narrows.

INTRODUCTION

Detailed geological mapping around Bathurst Harbour and Bathurst Narrows in southwestern Tasmania (fig. 1) has resulted in the need to redefine the stratigraphic units in the area. This paper deals with the redefinition of units in lower-grade metamorphic rocks which are faulted against metaquartzite and phyllite metamorphosed to the garnet grade of the greenschist facies. In this paper, the metaquartzite and phyllite sequences are referred to as "metamorphosed" rocks. Their stratigraphic terminology is not discussed. Previous terminology defined for the lower-grade rock units has been published by Jennings (1960) and Stefanski (1957). The relationship between the units defined by Stefanski was unclear, and type sections were not defined. Hence his terminology is invalid. Jennings established the order in which the rock sequences occurred, but produced an incomplete stratigraphic column. He also did not adequately establish type sections and stratigraphic thicknesses. The correlation of sequences at Bathurst Harbour with sequences at the Crossing River (Bowen and MacLean 1971) was based on the incomplete section of Jennings (1960) at Bathurst Harbour and therefore cannot be considered valid.

DISTRIBUTION OF AND RELATIONSHIP BETWEEN SEQUENCES

A geological map of the area (fig. 1) shows three sequences, referred to as Proterozoic, probably Proterozoic, and Ordovician. The Preterozoic rocks are the southern continuation of the metamorphosed rocks of the Tyennan region elsewhere in Tasmania. They are dominantly quartzite, quartz schist and phyllite. Sedimentary structures have been preserved in places in these rocks, with well-developed cross-bedding, ripple-marks and mudcracks being common at Bramble Cove and to the east of Bathurst Harbour.

The Clytie Cove Group consists of five conformable formations which are delineated over the basin. The dominant rocks types in the sequences are conglomerate, graded poorly-sorted sandstone, and mudstone. The clasts making up the basal conglomerate beds of the Group are metaquartzite, quartz schist and occasional phyllite fragments. These clasts contain at least two tectonic surfaces which bear no geometrical relationship to

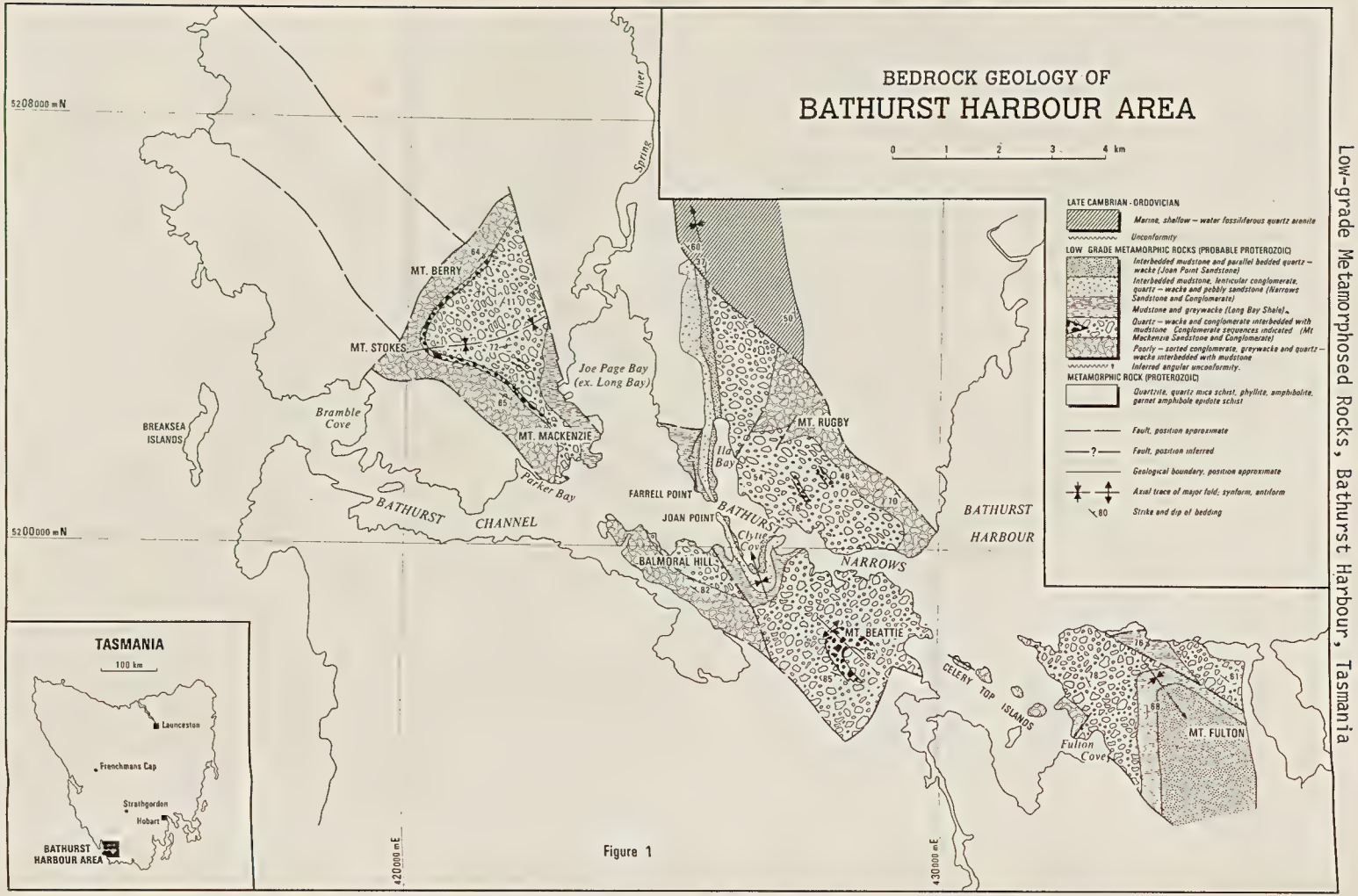
BEDROCK GEOLOGY OF
BATHURST HARBOUR AREA
0 1 2 3 4 km
LATE CAMBRIAN - ORDOVICIAN
Marine, shallow – water fossiliferous quartz arenite
Unconformity
LOW GRADE METAMORPHIC ROCKS (PROBABLE PROTEROZOIC)
Interbedded mudstone and parallel bedded quartz – wacke (Joan Point Sandstone)
Interbedded mudstone, lenticular conglomerate, quartz – wacke and pebbly sandstone (Narrows Sandstone and Conglomerate)
Mudstone and greywacke (Long Bay Shale)
Quartz – wacke and conglomerate interbedded with mudstone Conglomerate sequences indicated (Mt Mackenzie Sandstone and Conglomerate)
Poorly – sorted conglomerate, greywacke and quartz – wacke interbedded with mudstone
Inferred angular unconformity.
METAMORPHIC ROCK (PROTEROZOIC)
Quartzite, quartz mica schist, phyllite, amphibolite, garnet amphibole epidote schist
Fault, position approximate
Fault, position inferred
Geological boundary, position approximate
Axial trace of major fold; synform, antiform
80 Strike and dip of bedding
5208000 m N
5200000 m N
420000 m E
430000 m E
MT. BERRY
MT. STOKES
MT. MACKENZIE
MT. RUGBY
MT. BEATTIE
MT. FULTON
Joe Page Bay (ex. Long Bay)
Bramble Cove
BREAKSEA ISLANDS
Parker Bay
BATHURST CHANNEL
FARRELL POINT
JOAN POINT
BALMORAL HILL
Chine Cove
NARROWS
BATHURST HARBOUR
GELERY TOP ISLANDS
Fulton Cove
Spring River
Ila Bay
TASMANIA
100 km
Launceston
Frenchmans Cap
Strathgordon
Hobart
BATHURST HARBOUR AREA

Figure 1

the cleavages present in the matrix of the conglomerate. The clasts are indistinguishable from rocks cropping out in the surrounding metamorphosed Precambrian sequences.

The Clytie Cove Group is faulted against the metamorphosed rocks (fig. 1). However, clasts with disoriented cleavages and indistinguishable from the surrounding metamorphic rocks occur in the basal conglomerate beds and indicate that an unconformity existed between the two sequences prior to faulting. At least two deformation events affected the basement rocks prior to the deposition of the Clytie Cove Group.

The third distinct sequence lies between Mt Rugby and the Spring River [GR260050]. It is composed of siliceous clastic sedimentary rocks (conglomerate and well-sorted sandstone) and lies uncomformably on the metamorphosed Precambrian sediments. The boundary of these rocks with those of the Clytie Cove Group is a fault, but an age difference between them is inferred because of the differences in structural style and deformation history. Also, the unconformable contact with the metamorphosed rocks trends north-south, while the general fault-bounded trend of the Clytie Cove Group is north-west and the unconformity is truncated. The siliceous clastic rocks are fossiliferous, containing a gastropod with almost flat spiral coil which occurs in lithologically similar rocks containing Ordovician faunas elsewhere in southwestern Tasmania (M. Clarke, *pers. comm.*). These are thus correlated with the upper part of Denison Subgroup sequences elsewhere in Tasmania, which ranges in age from Late Cambrian to Early Ordovician (Corbett 1975).

STRATIGRAPHIC TERMINOLOGY OF THE SEQUENCES

(i) Metamorphosed rocks

No attempt has been made to define individual stratigraphic units in the metamorphic rocks. Taylor (1959) and Stefanski (1957) have defined units in areas surrounding Bathurst Harbour and on the south coast, but these definitions have not been extended or used in this work, as it has not been possible to establish stratigraphic relationships between the different metamorphic rock types.

The metamorphosed rocks of the Tyennan region in Tasmania are considered by all authors to be Precambrian. Recently Raheim and Compston (1977) indicated minimum metamorphic ages for rocks in the Frenchmans Cap area (fig. 1) and the Strathgordon area (fig. 1) ranging from 800 my to 550 my with major metamorphic events at 800 my and between 550 and 630 my. The available evidence suggests a Precambrian age of greater than 800 my for the rocks underlying the Tyennan region.

(ii) The Clytie Cove Group

Stefanski (1957) and Jennings (1960) have given stratigraphic names to the less metamorphosed, sedimentary sequences at Mt Fulton and around Bathurst Narrows. The Davey Group has been a widely used name for some years (David 1932), but it has been used by Carey (1947), Hills and Carey (1949) and David (1932, 1950) for both the metamorphosed and less metamorphosed rocks in the area. It is thus inappropriate for the purposes of current work.

Table 1 shows the names used in this work and their relationship to the names used by Jennings (1960) and Stefanski (1957). The nomenclature proposed in this paper follows the established terminology as closely as possible, but it has been necessary to redefine Jennings' units and rescind those of Stefanski. Stefanski did not rigorously define his units, and did not state their exact geographical locations. The formations he used did not have tops and bottoms and the relationship between them was not established. The author therefore considers them invalid. A new group name is introduced and defined, the Clytie Cove Group.

The Clytie Cove Group consists of five formations, defined below, which were deposited as a conformable sequence of rocks. It is defined as that succession of rocks around Joe Page Bay and Bathurst Narrows which consists of five formations: Mt Rugby Conglomerate at the base, Mt Mackenzie Sandstone and Conglomerate, Long Bay Shale, Narrows Sandstone and Conglomerate, and Joan Point Sandstone at the top. Clytie Cove lies in the central part of the major syncline, on the axial trace of which the highest stratigraphic unit

TABLE 1

PUBLISHED STRATIGRAPHIC NAMES

This work	Jennings, 1960	Stefanski, 1957	Thickness (m)
Joan Point Sandstone	--	--	150
Narrows Sandstone and Conglomerate	--	--	200
Long Bay Shale	Long Bay Shale	Varvoid Bay (?)	300
Mt Mackenzie Sandstone and Conglomerate	Mt Mackenzie	Beattie	600
Mt Rugby Conglomerate	Mt Rugby	Fairy Tale Head (?)	500

occurs [GR266966]. The total thickness of the group is between 1750 m and 1850 m. A generalised stratigraphic column of the group is shown in figure 2, which shows the general fining-upwards nature of the sequence and the stratigraphic location of major conglomerate units.

(a) Mt Rugby Conglomerate - The Mt Rugby Conglomerate is defined as that sequence of conglomerate, sandstone and mudstone east of the fault on the SW margin of the outcrop area below the Mt Mackenzie Sandstone and Conglomerate cropping out in a line from GR225012 to GR228020 across the southern extension of Mt Mackenzie. The formation forms the major topographic highs in the area, such at Mt Mackenzie [GR223020], Mt Stokes [GR200037] and Mt Berry [GR207050]. Mount Rugby [GR269023] and Balmoral Hill [GR244998] are underlain by correlates of this formation. The conglomerate at Mt Rugby is on the opposite limb of the major syncline to the type section. The stratigraphic units are symmetrical about the synclinal hinge trace. The Mt Rugby Conglomerate passes gradationally into the overlying sandstone and conglomerate. The transition zone is narrow. The formation is 500 m thick in the type section but lateral thickness variations are common. The lower boundary is a fault against metamorphosed Precambrian basement rocks (quartzite and conglomerate). It is exposed on the shoreline at GR225012. The lithology of the formation is variable, consisting of massive conglomerate, conglomerate with aligned clasts and well-defined bedding and conglomerate with thin sandstone and mudstone. Jennings (1960) used the name for similar rocks to those included in the present definition but did not give a type section.

(b) Mt Mackenzie Sandstone and Conglomerate - The Mt Mackenzie Sandstone and Conglomerate is defined as that sequence of rocks conformably overlying the Mt Rugby Conglomerate on the eastern flank of Mt Mackenzie, and overlain gradationally by the Long Bay Shale. The formation crops out throughout the valleys to the south and east of Mt Berry and Mt Mackenzie. The type section is at Mt Mackenzie (from co-ordinates 220028 to 225022) where the formation has a minimum thickness of 600 m. The formation fines upwards from a sandstone-conglomerate sequence to a sandstone-siltstone sequence overlain by a succession of interbedded mudstone and medium- to fine-grained sandstone.

Correlates of this formation occur on Mt Beattie [GR282983], Mt Rugby and around the northern and southern foreshores of Bathurst Narrows. Lateral thickness variations are common, and some major conglomerate lenses occur in this formation and its correlates. In the type section the formation contains fine conglomerate with aligned pebbles at the base, with or without graded-bedding and cross-bedding. The fine conglomerate passes upwards into clean, well-sorted sandstone with medium-scale cross-bedding and scour and channel structures. Above this, siltstone and fine-grained sandstone show load casting, small scale cross-bedding of the festoon type, and convolute lamination.

The formation as defined above is equivalent to the Mackenzie Conglomerate of

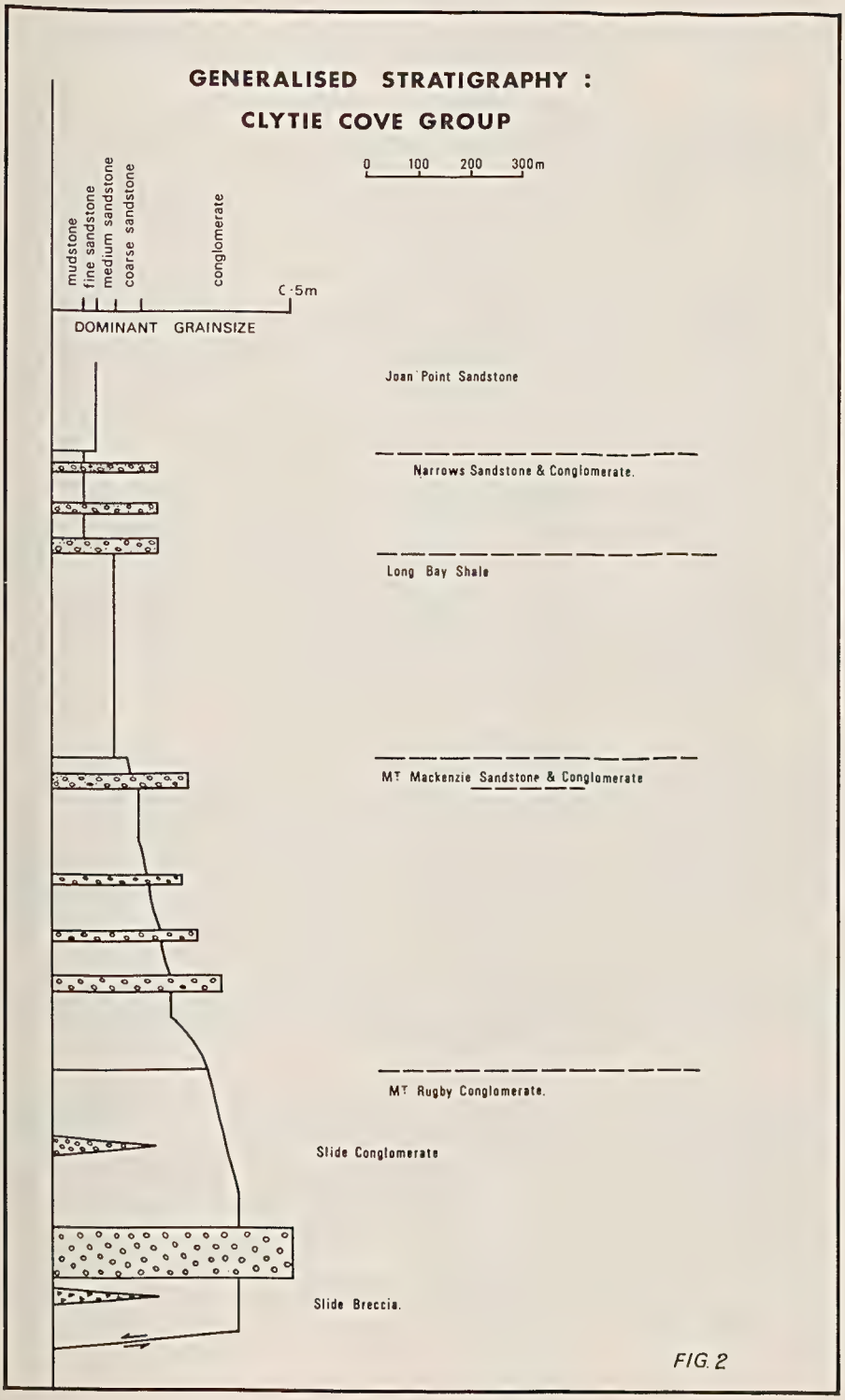
GENERALISED STRATIGRAPHY :
CLYTIE COVE GROUP
0 100 200 300m
mudstone
fine sandstone
medium sandstone
coarse sandstone
conglomerate
0·5m
DOMINANT GRAINSIZE
Joan Point Sandstone
Narrows Sandstone & Conglomerate.
Long Bay Shale
Mt Mackenzie Sandstone & Conglomerate
Mt Rugby Conglomerate.
Slide Conglomerate
Slide Breccia.

FIG. 2

Jennings (1960) for which a type section was not given. The Beattie Formation of Stefanski (1957) is a probable correlate of this and is also without adequate definition or location. Consequently the name Beattie Formation is declared invalid.

(c) Long Bay Shale - The Long Bay Shale is defined as that sequence of interbedded mudstone, siltstone, sandstone and minor conglomerate cropping out along the southeastern shoreline of Bathurst Channel opposite Joe Page Bay between coordinates 257999 and 262998. The sequence grades downwards into a sandstone sequence correlated with the Mt Mackenzie Sandstone and Conglomerate. It is overlain conformably by the Narrows Sandstone and Conglomerate. A possible fault exists in the type section, and the amount of the succession missing is uncertain. In the type section the formation consists of sandstone beds less than 0.5 m thick interbedded with thinner siltstone and mudstone beds. The ratio of sandstone to mudstone and siltstone is overall less than one. The sandstone is graded and laminated, sometimes with a ripple-marked top. Finer-grained beds often show all the Bouma divisions. This formation has a minimum thickness of 300 m in the type area. In Joe Page Bay [GR250020] the thickness reaches 400 m. The Long Bay Shale is correlated with rocks referred to by Jennings (1960) as the Long Bay Shale and his name retained although the type section defined above is not on the shores of Joe Page Bay (ex Long Bay). Jennings (1960) did not define a type section. The Varvoid Bay Group (Stefanski 1957) is also a probable correlate of the Long Bay Shale (Jennings 1960). Rocks north of Mt Fulton [GR350967], at the probable location of Varvoid Bay (an unused name), are of many types and as Stefanski (1957) did not show the group on a map and the geographic location is uncertain, the name should no longer be used.

(d) Narrows Sandstone and Conglomerate - The Narrows Sandstone and Conglomerate is defined as that sequence of rocks cropping out as a topographic high along Farrell Point [GR257008] and Joan Point [GR258006]. The type section is located on the tip of Farrell Point. It consists of coarse- to very coarse-grained conglomerate with moderate to well-rounded clasts, interbedded with finer-grained conglomerate showing cross-bedding and graded bedding. Sandstone and mudstone units also occur, the sandstone showing features typical of the underlying formation. Scours and channels are common at the base of conglomerate beds.

The section is 200 m thick and is underlain conformably by the Long Bay Shale and overlain conformably by Joan Point Sandstone. The contact with the former is sharp but the latter boundary is gradational.

(e) Joan Point Sandstone - The Joan Point Sandstone is that sequence of interbedded sandstone and mudstone cropping out from Joan Point to Clytie Cove [GR265997] and along the western shore of Ila Bay [GR260014]. It conformably overlies the Narrows Sandstone and conglomerate. The top is not exposed. It is at least 150 m thick. The type is defined as the section from Joan Point to Clytie Cove between co-ordinates 260006 and 265997. The section is very nearly parallel to the strike. The Joan Point Sandstone consists of interbedded sandstone and mudstone. The ratio of sandstone to mudstone is high. The sandstone beds are about 0.2 m thick with scoured bases. They begin with a graded division and pass upwards into parallel lamination and then into convolute lamination. Convolute lamination is a characteristic feature of this formation. The sandstone is moderately- to poorly-sorted and the beds are laterally continuous over large distances.

Jennings (1960) apparently included these last two formations in the Long Bay Shale.

(f) Correlates of the Clytie Cove Group at Mt Fulton.- Four units can be recognised on Mt Fulton. The basal unit consists of coarse-grained conglomerate with interbedded sandstone and mudstone and crops out on the western side of Mt Fulton, north of Fulton Cove [GR365928] and on the Celery Top Islands (*e.g.* GR308977). It is about 250 m thick. It is correlated with the upper part of the Mt Rugby Conglomerate. The base of the sequence is faulted out.

The second formation consists of interbedded sandstone and conglomerate which show marked lateral facies changes. The sequence has a minimum thickness of 500 m and is correlated with the Mt Mackenzie Sandstone and Conglomerate.

Conformably overlying this correlate of the Mt Mackenzie Formation is a sequence of medium-grained sandstone with flute marks, graded-bedding, convolute lamination and numerous scours interbedded with mudstone or finely laminated mudstone. It is 190 m thick, and is correlated with the Long Bay Shale.

Five hundred metres of sandstone, conglomerate and mudstone conformably overlie the correlate of the Long Bay Shale. The conglomerate horizons lie high in the sequence. The section above the Long Bay Shale correlate is correlated with the Joan Point Sandstone, even though no conglomerate occurs in that formation. There are no conglomerate horizons low in the section enabling correlation with the Narrows Sandstone and Conglomerate.

In a sequence such as the Clytie Cove Group lateral facies changes are the norm rather than the exception and so a strict lithological correlation between regions is not to be expected. The general features of the columns in both regions are similar and indicate the same depositional system. The total thickness of the column at Mt Fulton 1440 m compared to about 1850 m for the generalised column at Clytie Cove. This difference is partly due to faulting at the base of the Mt Fulton sequence.

CORRELATION OF THE CLYTIE COVE GROUP WITH SEQUENCES IN THE CROSSING RIVER AREA

The Clytie Cove Group consists of three interbedded rock-types: (i) graded bedded sandstone and siltstone; (ii) graded bedded and ungraded conglomerate and pebbly sandstone; and (iii) mudstone. Different parts of the column contain differing proportions of the three types of beds. The sandstone beds show typical features of turbidites such as graded-bedding, sole marks, Bouma sequences (Bouma 1962) and sharp, erosional bases and gradational tops. Consequently it is inferred that deposition of the Clytie Cove Group took place in a basin which was receiving turbidity currents throughout its history. The conglomerate beds are also considered to have been deposited by subaqueous gravity flows (Middleton and Hampton 1973) because they are interbedded with the sandstone beds. The sequence therefore contains a significant proportion of resedimented conglomerate.

Bowen and MacLean (1971) argued that rocks unconformably overlying the metamorphosed Precambrian rocks near the junction of the Crossing and the Davey Rivers are lithologically and structurally equivalent to those at Bathurst Harbour. This is not the case. The rocks described by them are non-marine terrestrial fanglomerate and fluvial conglomerate which were correlated with the Owen Conglomerate (a correlate of part of the Denison Sub-Group of Late Cambrian to Early Ordovician age) (Bowen and Maclean 1971). Williams (1979) has shown that the sequence at Bathurst Harbour is a subaqueous accumulation in relatively deep water.

The sequence of structural events within the Clytie Cove Group is much more complex than that in the sequence at the Davey River (Bowen and MacLean 1971). In the Davey River area structural conformity is inferred between rocks which were correlated with the Caroline Creek Sandstone and the underlying conglomerate sequences.

At Mt Rugby, the fossiliferous sandstone and conglomerate were simply deformed during one fold phase, producing folds on shallowly northnorthwest plunging hinge lines. The conglomerate and sandstone of the Clytie Cove Group were deformed during four deformation events, producing vertically plunging major folds and refolded fold hinge lines. A structural break is inferred between the two sequences.

Consequently the correlation of conglomeratic sequences at the Davey River with the conglomeratic sequence at Bathurst Harbour (the Clytie Cove Group) is not valid.

Low-grade Metamorphosed Rocks, Bathurst Harbour, Tasmania

SUMMARY

The sequence of low-grade metamorphic rocks faulted against higher-grade metamorphosed rocks at Bathurst Harbour in southwestern Tasmania forms the Clytie Cove Group consisting of five formations: the Mt Rugby Conglomerate (base),Mt Mackenzie Conglomerate, Long Bay Shale, Narrows Sandstone and Conglomerate, and Joan Point Sandstone. These are derived from rocks underlying the Tyennan region which consists of the higher-grade metamorphosed rocks. The sequence is overlain with an inferred unconformity by correlates of the Denison Sub-Group (Late Cambrian to Early Ordovician in age). Previous stratigraphic correlations (Bowen and Maclean 1971) are probably incorrect.

ACKNOWLEDGEMENTS

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(ms. received 13.2.1981)

PYROCLASTICS IN THE UPPER PARMEENER SUPER-GROUP, NEAR BICHENO, EASTERN TASMANIA

by C.A. Bacon and J.L. Everard
Department of Mines, Hobart

(with two tables, three text figures and one plate)

ABSTRACT

BACON, C.A. and EVERARD, J.L., 1981 (30 ix). Pyroclastics in the Upper Parmeener Super-group, near Bicheno, eastern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 29-36 (with three figures and one plate). ISSN 0080-4703. Department of Mines, Hobart, Tasmania Australia.

Extensively altered, poorly welded ash-fall tuffs of rhyolitic to rhyodacitic composition occur both *in situ* within the Upper Parmeener Super-Group and as loose talus, at five localities up to twelve kilometres apart in the vicinity of Bicheno in eastern Tasmania. Three closely spaced tuff layers up to 0.7 m thick have been intersected in a drill hole. These and the four outcrops may represent the same stratigraphic interval. The rocks contain phenocrysts of embayed quartz, kaolinized feldspar and altered vermiculite in a devitrified matrix of quartz and kaolinite, in which may be discerned relict glass shard and bubble structures. In some localities, the vermiculite has been thermally exfoliated, suggesting heating to more than 300°C during the intrusion of nearby Jurassic dolerite. Rhyolite, probably derived from unlocated Triassic flows, occurs as clasts within Triassic conglomerate float and as pebbles within Quaternary river gravels.

INTRODUCTION

Triassic volcanism in Tasmania, contemporaneous with the deposition of the Upper Parmeener Super-Group, has long been suspected. Lewis and Voisey (1938) described beds of tuffaceous rock bearing fragments of altered volcanic rock, within coal-bearing Late Triassic feldspathic sandstones at New Town, near Hobart. Hale, in Spry and Banks (1962), described volcanic fragments as "ubiquitous" in the litharenites of the Tasmanian Triassic, and commented that igneous activity appeared to have been increasing during the period. Spry (*ibid.*) noted that no Triassic lavas had been found, but the only other possible source was limited outcrops, over one hundred kilometres away, of fine-grained Cambrian volcanics which would be unlikely to survive travel in water for that distance.

This paper describes acid pyroclastic rocks occurring as outcrop and in drill core within the Triassic sequence and as loose talus, at five localities near Bicheno, Tasmania (table 1 and fig. 1). Reworked fragments of rhyolite occur in the district as clasts within Triassic conglomerate float and in Quaternary river alluvium. All samples were collected by the senior author in 1979 during an Honours project, except for sample 47851 which was collected by Mr P. Sansom of the Shell Company.

LOCAL GEOLOGY

Adamellite of Late Devonian age crops out near Bicheno, in the eastern part of the area. Drill hole data indicates that the adamellite directly underlies sediments belonging to the Upper Parmeener Super-Group (Forsyth *et al.* 1974), on Buster Ridge, southwest of Bicheno (Bacon 1979). North of Bicheno, in Department of Mines, D.D.H. Bicheno 5 (FP040677) Siluro-Devonian Mathinna Beds form the basement.

Marine limestones belonging to the Lower Parmeener Super-Group (Forsyth *et al.* 1974) disconformably overlie the basement north of Bicheno. The limestone does not crop out, but has been intersected in D.O.M. D.D.H. Bicheno 5 (FP040677) and Bicheno 4 (EP994636). Overlying and interbedded with the limestone are well sorted super-mature quartz arenites.

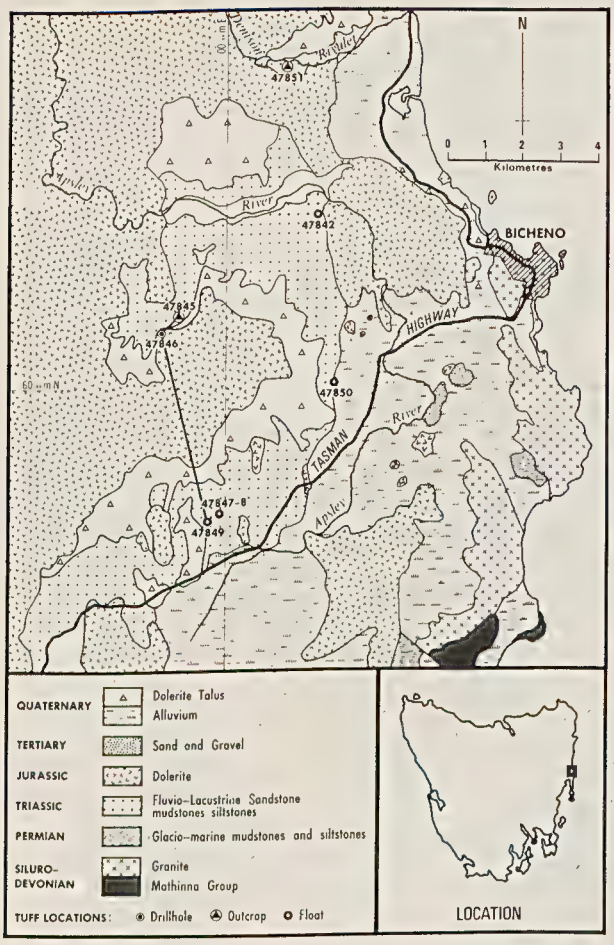

FIG.1.- Locality map.

Overlying the marine sediments is a fluvial sequence belonging to the Upper Parmeener Super-Group (Forsyth *et al.* 1974), consisting of minor quartz arenites (different from those associated with the marine sediments), overlain by quartz-rich litharenites which in turn are overlain by "quartz-poor" litharenites interbedded with shale, mudstone, siltstone, conglomerate, coal and rare tuff.

Jurassic dolerite has intruded the fluvial sequence. Large flat lying areas surrounding the Apsley River are covered with a thick layer of Quaternary alluvium.

FLORA AND AGE

Forsyth (1980) described the following palynomorphs from a sample of siltstone from the bed of the Denison Rivulet, less than 50 m stratigraphically below sample 47851: *Alisporites australis* De Jersey 1962; *Anapiculatisporites pristidentatus* Resier and Williams, 1969; *Annulispora folliculosa* (Rogalska) De Jersey 1959; *Apiculatisporis globulus* (Leschick) Playford and Dettman 1964; *Aratrisporites* sp. *cf. A. coryliseminus* Klaus (poor preservation prevents positive identification); *Dictyophyllidites mortoni* (De Jersey) Playford and Dettman 1965; *Neoraistrickia* sp.; *Stereisporites antiquasporites* (Wilson and Webster) Dettman 1963; *Stereisporites* sp. A. De Jersey 1970; *Uvaesporites verrucosus* (De Jersey) Helby *nov.* De Jersey 1971; A very poorly preserved specimen could be *Semiretisporis denmeadi* (De Jersey) De Jersey 1970.

Forsyth (1980) assigned the microflora to the *Craterisporites rotundus* Zone, suggesting correlation with the Ipswich Coal Measures and therefore a probable Carnian age (De Jersey 1971, 1975).

Fragments of *Dicroidium odontopteroides* var. *odontopteroides* occur in one outcrop of pyroclastic rock (47851), indicating an age range of Late Anisian to Norian (Retallack 1977) for the rock.

The age of the pyroclastic rocks is, then, Late Triassic; probably Carnian and possibly Norian.

PETROGRAPHY

Welded tuff

At all five localities the welded tuffs are lithologically similar, with only minor variations in grain size, mineral abundance, degree of alteration and development of lamination. They are hard off-white to buff-coloured rocks consisting of abundant (5-15%), fine grained (<1 mm) phenoclasts of vermiculite, kaolinized feldspar, quartz and accessory haematite, zircon and (?) ilmenite in a cryptocrystalline matrix of devitrified glass (85-95%). The rocks typically display a well developed, wavy to streaky, horizontal lamination defined by variations in the colour, composition and grain size of the matrix and the abundance and, to a lesser extent, the alignment of phenoclasts.

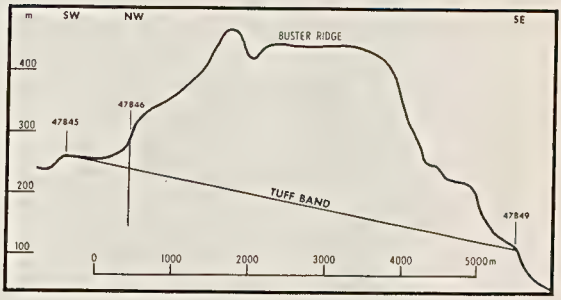

FIG.2.- Section through Buster Ridge showing relationship of tuff occurrences.

The largest phenoclasts (<1 mm, commonly about 0.3 mm) are deep orange-brown vermiculites, probably formed by the alteration of biotite. Pleochroism is absent or very weak, birefringence is probably moderate although anomalous green-blue predominates, and extinction is parallel to the cleavage. The mineral is optically negative and uniaxial or nearly so. The shape of the phenoclasts ranges from euhedral or subhedral pseudchexagonal basal sections, to distorted rectangular laths and ragged anhedra. Many are rounded or embayed, suggesting corrosion within the magma before extrusion. Except in sample 47846, many are distorted, with curved or radiating cleavage and wavy or fanning extinction. Parting along the cleavage is common. In places the texture of the surrounding matrix is disrupted. These features are attributed to thermal exfoliation of the vermiculite, caused by intrusion of Jurassic dolerite, which in the case of 47845 crops out 5 to 10 m stratigraphically above on the hillside. According to Deer *et al.* (1962, p.251) heating to more than about 300°C is required.

The vermiculites themselves are often partly or completely altered to colourless to pale yellow, low birefringence clay minerals. Partial analysis by electron microprobe of altered vermiculites from 47845 showed compositions either close to kaolinite or to a highly aluminous three-layered, dioctahedral phyllosilicate such as pyrophyllite or the smectite, beidellite.

Four stages are envisaged in the alteration of the original biotite:

(a) Alteration of biotite to vermiculite, probably soon after deposition, by hydrothermal action with the volcanic ash at temperatures of less than 250° to 300°C (*cf.* Roy and Romo 1957).

(b) Thermal exfoliation of vermiculite to over 300°C during the intrusion of Jurassic dolerite.

(c) Low temperature leaching of Mg, and addition of Al from the matrix, to form beidellite, probably with montmorillonite forming as an intermediate stage. Both minerals are well known as alteration products of tuff and volcanic ash, particularly under alkaline conditions (*ibid.* pp.240-241).

(d) Further leaching and weathering of beidellite, to form kaolinite (*ibid.* p.241).

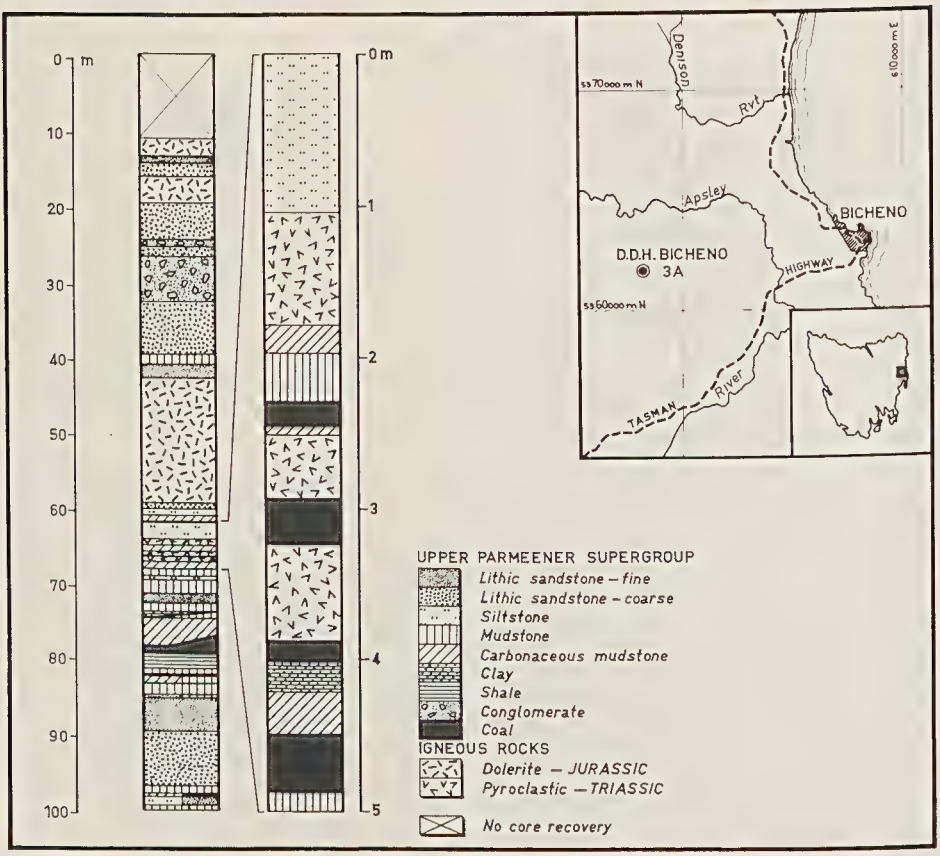

FIG.3.- Graphic log of Department of Mines, Bicheno, Diamond Drill Hole 3A.

The most abundant phenoclasts are altered feldspars occurring as oriented laths (typically 0.2 mm x 0.4 mm), oblong squat euhedra and subhedra, and numerous smaller (0.1 - 0.2 mm) anhedra. Often they are embayed suggesting resorption into the magma. All phenoclasts are completely altered to a very fine (0.002 - 0.010 mm) low birefringence aggregate, probably consisting largely of kaolinite and quartz.

Quartz occurs as scattered, small (0.1 - 0.3 mm), sometimes embayed, equidimensional, angular subhedra and anhedra, sometimes with wavy extinction. Accessories include small quantities of anhedral to subhedral, almost opaque to very deep red haematite grains (0.05 - 0.10 mm) and traces of minute zircons and (?) ilmenite.

The matrix is a colourless to pale grey cryptocrystalline devitrified glass, probably largely consisting of silica and clay minerals (e.g. kaolinite and/or smectite). Within it may be discerned sometimes flattened, crescentic to rarely circular structures a few tenths of a millimetre long, sometimes apparently fused together. These represent broken, deformed shards and unburst bubbles of devitrified volcanic glass. They tend to be oriented parallel to the lamination (plate 1).

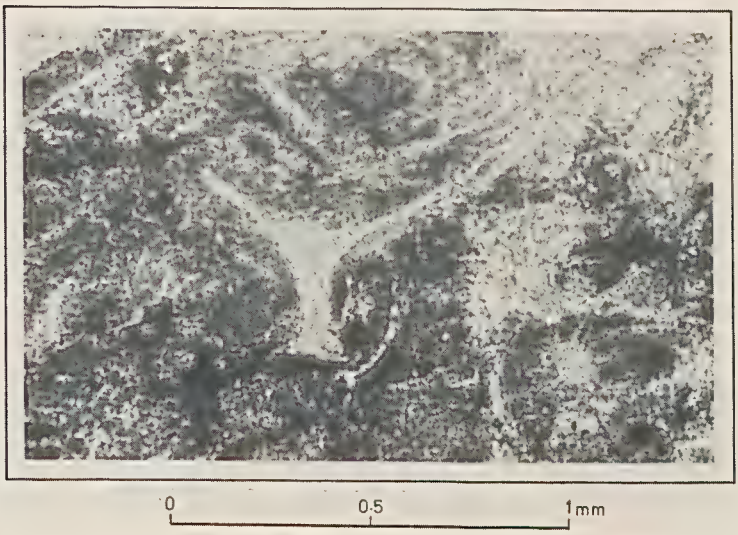

PLATE 1.- A well-developed glass shard in ignimbrite, nicols crossed. University of Tasmania Catalogue No. 47845. Photo: D. Seymour.

The relict, slightly deformed vitroclastic texture suggests that the rock is a poorly welded, ash-fall tuff, formed by aerial deposition of ash following explosive volcanic activity. Weak compaction resulted in some welding of the glass shards while they were still hot, accentuating the depositional lamination.

There is apparently no consistent lateral variation in the grain size of the pyroclastic rocks. Specimens 47846 and 47847 have the fewest (5%) and the smallest (≤0.3 mm) phenoclasts, whilst 47848 and 47849 have the most (15%) and the largest (≤1 mm). However, vertical variation in grain size is rapid and, although not observed on an outcrop scale, can be seen in thin section. The sorting is attributed to aeolian differentiation of ash. Together with the existence of three discrete layers of tuff, at least in D.O.M. Bicheno D.D.H. 3A, the rapid vertical variations in grain size suggest intermittent emission of ash, perhaps from several widely spaced vents.

TABLE 1

LOCALITY OF SPECIMENS

Sample No.*	AMG Reference	Lithology	Other Comments
47845	EP989619	Pyroclastic	Outcrop
47846	EP981618	Pyroclastic	Drill core
47847	EP997567	Pyroclastic	Talus
47848	EP997567	Pyroclastic	Talus
47849	EP995566	Pyroclastic	Talus
47851	FP014686	Pyroclastic	Outcrop
47852	FP025646	Rhyolite	Pebble - in Quaternary river alluvium
47850	FP028601	Conglomerate	Float - with rhyolitic clasts

* University of Tasmania Catalogue

RHYOLITE

Rhyolite pebbles occur within unconsolidated Quaternary river alluvium in the valley of the Apsley River. Specimen 47842, a portion of a water-worn elongate pebble, is a fine-grained, pale yellow-grey to beige-coloured rock. It consists of partly-saussuritized and often embayed euhedral to subhedral laths and squat phenocrysts (2.0 - 0.5 mm) of sanidine (5%) enveloped in a matrix of abundant, very fine-grained (rarely 0.1 mm, ranging to a few thousandths of a mm) quartz grains and straw-yellow cryptocrystalline devitrified glass. The quartz grains are well-rounded and subspherical to ellipsoid with their long axes aligned, to form a very well developed and macroscopically visible flow lamination, which parts to curve and wrap around each sanidine phenocryst. Fibrous ghost structures suggestive of completely altered biotite and a fine (<0.01 mm) sprinkling of inconspicous (?) ilmenite occur throughout the matrix.

Angular blocks of conglomerate (47850) found in paddocks are most probably derived from a conglomerate band in the Triassic fluvial sequence now covered by talus. However, a Triassic age for the conglomerate has not yet been proved. The conglomerate is composed of large (up to 0.1 m in diameter) well-rounded, equant to elongate, lithic clasts in a medium-grained litharenite matrix. The clasts are of black siltstone, white and pink quartzite with rare inclusions of garnet, rhyolite, and two varieties of welded tuff. All the volcanic clasts are strongly weathered.

CHEMICAL ANALYSES

Three analyses of welded tuffs and a partial analysis (by broad area electron microprobe scans) of rhyolite are given below:

TABLE 2

CHEMICAL ANALYSES OF THE PYROCLASTICS

Sample No.*	47851	47845	47847	47852
Reg. No.**	800285	800286	800287	-
SiO_2	70.60	78.60	77.10	78.33
TiO_2	0.35	0.19	0.67	0.23
Al_2O_3	14.30	12.00	13.00	11.11
Fe_2O_3	0.83	0.91	0.5	1.73†
FeO	1.40	0.29	0.71	
MnO	0.06	<0.01	<0.01	<0.20
MgO	0.45	0.20	0.15	0.20
CaO	1.40	0.08	0.11	0.64
Na_2O	0.40	0.05	0.05	1.68
K_2O	2.50	1.30	3.60	6.36
CO_2	0.70	-	-	n.d.
H_2O^+	4.40	4.00	3.90	n.d.
H_2O^-	1.90	1.80	0.66	n.d.
Total	99.27	99.42	100.00	n.d.

* University of Tasmania Catalogue. n.d. not determined.
† total iron reported as FeO.
** Department of Mines, Launceston.
\- not detected

The welded tuffs are rhyodacitic (47851) to rhyolitic (47845, 47847) in composition. The High H_2O^+ values result from alteration of the feldspars, the glassy matrix and, later, the vermiculites to clay minerals. This process has also led to the depletion of the rocks in Na_2O and CaO, whilst K_2O appears to be better retained, possibly in the more resistant vermiculite.

The amount of H_2O^+ is sufficient to account for almost all of the Al_2O_3 as kaolinite, suggesting that the devitrified matrix (85-95%) of each rock is largely kaolinite and quartz.

Allowing for differences in the method of analysis and in the degree of alteration, especially the better retention of alkalis in the sanidine phenocrysts, the rhyolite appears to be close in composition to the welded tuffs.

CONCLUSION

It is probable on both stratigraphic and petrologic evidence that the five localities at which welded tuffs occur represent the same horizon. Minor lateral or vertical variations in grain size and mineralogy are attributed to aeolian sorting of ash, perhaps emitted intermittently from a number of vents. The lateral limits of the horizon, which may be stratigraphically useful, are unknown.

Reworked rhyolite pebbles in Quaternary alluvium and in conglomerate float in the district are thought to be derived from associated Late Triassic flows which have not yet been found *in situ*.

Recently reported alkali olivine basalts near St Marys (Calver and Castleden 1980) are significantly older (Middle Triassic), and their petrogenetic relation, if any, to these rocks is unknown.

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BUREAUCRATIC REFORM - A BUREAUCRAT'S PERSPECTIVE

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ABSTRACT

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Continuing bureaucratic reform of a positive and fundamental kind will occur in tandem with the progressive elevation of the political consciousness of the community at large.

INTRODUCTION

I have chosen to address the Society about bureaucratic change not only because I need an occasional change of diet from energy issues but because it is a subject of particular personal interest and one which is, I believe, central to any discussion of the kind of society we shall enjoy, tolerate or dislike in future decades. I offer no particular expertise as an analyst in this area - only interest and some measure of experience and direct involvement, having served under Ministers as disparate as Casey, Menzies, Barwick, Hasluck, McEwen, Wright, Howson, Stewart, Batt and Lowe. Three of those Ministers I never met, with some of them the contact was only fleeting and yet there are others whom I knew, or know, well and with whom I was in close professional contact. Perhaps my interest in this area has also been stimulated by service in both Federal and State Governments, as well as in fully-fledged departments, small so-called "policy units" and in a statutory authority. There is merit, you see, in being a nomadic administrator - a sort of Bedouin bureaucrat!

I should emphasise, too, that when I speak about bureaucrats and bureaucracies I shall be doing so by reference to the public sector. This is not to suggest, however, that there are not many more similarities between public sector and private sector bureaucracies than is perhaps usually conceded. I shall also mostly be talking about Government generally in Australia - at both State and Federal levels - rather than by reference to a particular Government, unless I indicate otherwise. Obviously, however, my chief reference points are the situations in Canberra and Hobart.

THE NEED FOR CHANGE

It seems to me that we should concern ourselves with the quality of our bureaucracies - with their modernity or otherwise, with the extent to which they adequately reflect broader socio-economic change - quite simply because the environment in which they operate has changed quite dramatically in only the past decade or so. The industrial revolution may have heralded the increasing involvement of the State in the affairs of ordinary citizens, whether as employers or employees, but at least in our kind of society the notion of Big Government is essentially a phenomenom unique to the middle decades of the twentieth century. Sadly, however, many of our institutions continue to reflect structures and attitudes more appropriate to earlier decades.

Government is now bigger, more complex and - largely in response to demand - much more heavily involved in our everyday affairs than was the case before the Second World War or even than in the fifties and early sixties. The various instruments of fiscal and monetary policy touch us all more often and more severely. Urban planning and welfare policies and environmental standards and energy policies and various other new initiatives or expanded activities in established areas, are the manifestations of big contemporary Government. The situation has been further complicated by the rapidity of technological change and, related to this, the information explosion. Associated with accelerating

international inter-dependence, inflation and unemployment are more readily "imported" and the policy-maker's information base grows daily more immense. Moreover, this ever-increasing data base may also contribute to some alienation of the ordinary citizen from the institutions which purport to serve him - to the development, if you like, of a "them and us" syndrome. The Government has a mass of data to which the citizen does not have effective access and which he may not readily comprehend - and the politician is confronted with the awesome task of explaining the rationale for a decision which, however well researched and equitable he considers it to be, does not appear to be sensible to Joe Bloggs. Joe is unlikely to be impressed by a Ministerial statement expressing confidence in a decision because it is based on the inverse matrix of the third generation of the input-output model developed for the Derwent Valley sub-region of the Tasmanian economy - particularly if it means that Joe is now out of a job!

I am not passing judgments about the rapidly changing environment in which Government now operates - I think the facts are self-evident. What is important are the consequences of this situation, for our institutions and the community at large. The immediate consequence is the immense pressure that is placed on our policy-makers, particularly Ministers.

THE BUREAUCRAT AS POLICY-MAKER

But who are they, these policy makers? I have already inferred that they do not include the ordinary citizen. It is true that the citizen may influence the process by virtue of his vote but it is arguable that he is casting his vote by reference to policy issues, even assuming that competing "policies" may be readily discerned - and their relative merits readily weighed - in the particular circumstances of an election campaign. Lindblom (1968) prefers to talk about proximate policy-makers. He asserts that "... not all citizens can be immediate or proximate, makers of policy. They yield the immediate (or proximate) task of decision to a small minority." Lindblom makes it very clear that he sees officials - bureaucrats, permanent and impermanent - as being very much part of this group.

I would further submit that this policy-making function is necessarily being yielded increasingly - in various ways and to varying degrees, depending on the system and the situation - by elected policy-makers to non-elected policy-makers. It is happening for all the reasons that I mentioned earlier in this paper. This process should be seen as sinister only if it is not recognised and not accommodated in adjustments to existing arrangements. If we are cavalier or apathetic about effecting such adjustments we shall put at risk the very system itself. One is reminded of Apter's observation (1970) about: "How urgent it becomes to civilize the civilizers, that is, to give those who know something about science and the public welfare a sensitivity to human rights and values. Without such sensitivity, the new technocrats will have little attachment to democracy." Apter was writing about the dangers inherent in the ethic of science becoming the ethic of man but the sentiments seem to me to be equally relevant to the situation of the bureaucrat as policy-maker.

I shall mention later some of the prescriptions that have been canvassed to accommodate this situation. What I am seeking to do at this point is to lay to rest the simplistic notion - the fiction, in fact - that Governments make policy and bureaucrats administer it. As Emy (1974) comments, "We can no longer (if we ever could) distinguish between policy (initiatives and goals laid down by the elected Minister) and administration (the application of policy by the public servant.) The public servant has become a policy-maker..." There are those who might respond to this by asserting that bureaucrats are concerned with facts and Ministers with values but, as Professor Spann (1976) observes, this " ... is attractively simple, but over-simple." Do bureaucrats - both as individuals and as corporate beings - not have values? Do they not intrude those values when they select their facts or put pen to paper or talk to their Ministers? Of course they do. To deny this is to deny that Patrick Shaw was not influential in the change of Australian policy regarding Indonesian claims on West Irian or to deny that the creation of the Australian Industry Development Corporation was not heavily influenced by Sir Alan

Westerman or to suggest that John Stone, Secretary of the Treasury, is some kind of ideological eunuch.

The facts never speak for themselves. Somebody selects them. Somebody speaks for them.

Suffice it to say that bureaucrats are among the proximate policy-makers. They do wield immense influence on the policy-making process - because they are very bright or thrusting or have strong views or simply because they are there, proximate to the point of decision; because they are custodians of the data base; because Ministers are busy men and need to be serviced; because they, the bureaucrats, are also custodians of the precedents - they are always there, whereas Ministers come and go - and to know what has gone before and to know about the feasibility of implementing alternative proposals is crucial information; and finally, among many other reasons, because the very volume of public business has required that more and more of the decision-making be formally or informally delegated to non-elected officials. While ultimate control remains, as it should, with elected Ministers not all these delegated functions are small and, taken as a whole, they are certainly not insignificant. Let us be quite frank about this: it is quite possible for a bureaucrat to send a company "to the wall" or to cause a pensioner immense discomfort quite simply because he interprets his mandate in a particular way and because, subjectively or otherwise, his own prejudices intrude into his response to a legitimate enquiry. In these circumstances, is it not crucial that we be concerned about the quality of the bureaucracy and the accountability of bureaucrats?

What all this also means is that not only is the distinction between policy and administration blurred but that the traditional notion of Ministerial responsibility has become eroded. The Royal Commission on Australian Government Administration - the Coombes Report (1976, p. 12) - addressed this point in the following terms: "Thus in a system which combines the anonymity of officials with an inability of Ministers effectively to accept responsibility, effective and economical administration can fall between the stools of the theory of ministerial responsibility and of the practice of management by anonymous officials." I shall pursue this point later in the paper. It is one which the Royal Commission canvassed at some length for it was concerned to balance " ... the demands of Ministerial responsibility and official accountability." (1976, p.13). To do this - to accommodate reality and yet preserve and protect the ultimate supremacy of elected Ministers and elected Parliaments - is surely fundamental to the maintenance of the kind of democracy we presently enjoy. It is also directly related to the nature and quality of policy-making.

OTHER DIMENSIONS OF THE PROBLEM

However, much of what I have been saying has related to the bureaucrat in a personalised, individual sense. He is, of course, also very much a corporate being and many of the problems requiring, and associated with bureaucratic change flow from this corporate role. In his book on "The Politics of Policy Making in (American) Defence and Foreign Affairs", Roger Hilsman (1971) observes that " ... a distinction must be made between the role and power of career officials acting as individuals and the role and power of career officials acting collectively as organisations." Elsewhere (1971, p. 45), he notes the fear of Congress - which he observes as having been sufficiently potent to influence legislation on foreign service matters - that the service " ... is manned not by typical Americans but by 'striped-pants cookie pushers' - socialites from effete, Eastern seaboard upper class families - and that their long service abroad leads them to become too cosmopolitan to represent the United States effectively."

This illustrates an eternal problem in all bureaucracies and the irony is that the causes and motives may, in other circumstances, be positive and healthy. The trouble is that the line between a positive esprit de corps and a negative ghetto mentality is a fine one. So, too, is the line between a positive preoccupation with function and the provision of service on the one hand and, on the other, introspection, conservatism and "fear of the dark" - whether the dark be represented by change, innovation or challenge.

In short, all bureaucratic organisations develop their own particular ethos, the special characteristics of which will flow from any or all of such factors as the nature of the leadership, the function, the predominant discipline, geographical location, degree of autonomy and so on. National Development has a view of the world that is quite different from the Treasury view and the Trade and Resources view is different again. There is nothing new in this. It is natural and inevitable but - particularly in those cases where an ethos is well entrenched, where autonomy has been jealously preserved and where external intrusions have been minimal - it invariably leads to a disproportionate preoccupation with the status quo, with a resistance to change. Even this may be healthy - particularly where change is being promoted, for its own sake as it were, without adequate forethought - but it may often also be very unhealthy.

Dror (1978) comments that: "Many studies have indicated that most people in most cases strongly resist change, especially when the changes would be in institutions that have an emotional and ideological significance, as most components of the public policy-making system do..."

One of the consequences of this phenomenom is that, where Governments perceive a need to provide new services or to accommodate new demands for policy initiative, they invariably have to give organisational effect to these needs and demands by way of arrangements that are essentially cosmetic. Special policy units or new statutory authorities are often manifestations of this organisational engineering and, where a new Department is created, it may often take a long time before it is accepted - and becomes effective - as an integral member of the family of departments and instrumentalities. Whatever its precise form, it is an object of suspicion; it is new; it will impinge upon, or erode, the responsibilities of others in the family.

Put another way, I would cite the example of Government's stance on environmental issues, on which I have been the recipient of countless representations from conservationists. It seems to me - assuming there is substance to the conservationists' case - that he can only expect greater sensitivity to environmental issues to become the order of the day in Government when the values and principles involved more thoroughly pervade community attitudes generally and hence become part of the baggage carried by policy-makers at all levels of the system. When we talk about changes to entrenched value systems we are talking about change which is at once both fundamental and necessarily incremental. Hence the need for organisational surgery of the cosmetic variety while bureaucratic institutions move slowly and cautiously towards reflecting changes in established value systems. One is reminded of Schaar's (1971) observation that "Before there can be a democratic organisation there must first be a democratic mentality ..."

Problems that impede orderly policy-making may also flow from such factors as bureaucratic power struggles which may, in turn, derive from various factors - some of an historical nature; others relating, for example, to political disputation. The Department of Foreign Affairs is perhaps a case in point. Traditionally, this Department has had a generalist orientation in its staffing and the nature of Australian society - where the political emphasis has been on domestic and developmental issues - would seem invariably to have resulted in the department having less influence than some other departments, in Cabinet and in the resolution of inter-departmental conflict. The result has been that the Department of Foreign Affairs has not, in my view, acted as comprehensive a co-ordinator of foreign affairs as has generally been the case with the State Department in the United States or the Foreign Office in the United Kingdom. Trade and Resources retains primacy in the field of trade policy and trade negotiations, as does Treasury in the area of foreign exchange policy, as does Transport in the area of international civil aviation policy, as does defence in the area of defence policy and so on - and, in many of these areas, Foreign Affairs is only hovering on the margins in the development and administration of policy in these various fields which impinge directly on the totality of our foreign policy. We thus tend to have a pigeon-holed foreign policy based on various bureaucratic fiefdoms and the opportunity for policy "trade offs" is diminished accordingly. For example, I can recall - as an officer in the Department of Trade - negotiating on commodity matters with United States officials from the State

Department. Our own foreign service officials were very much on the fringe of the negotiations whereas their American opposite numbers were presenting the US position. The bureaucrat caught up in this situation will develop a perception of his role that is attuned to the realities of his environment. Some will leave for new pastures; a few will fight for positive change; most will accept the situation.

This situation is unlikely to change while primacy in the foreign aspects of a particular portfolio is coveted by the Minister concerned - as it doubtless always will be. Besides, where the Minister's stance shows signs of weakening, there is likely to be compensatory pressure for maintenance of the status quo from his departmental advisers.

While I am not familiar with the detail, I suspect that the current difficulties being experienced in relation to air-fare policies with Europe and ASEAN countries is probably a further example of this problem. However, perhaps the best example - as well as being the most public and acrimonious example - of political disputation intruding into the bureaucracy and causing distortions of one kind or another occurred in the late 1960's. I refer, of course, to the antagonism between Messrs. McEwen and McMahon - and, to a lesser degree, between their respective departments - which resulted in much normal policy conflict being resolved more by political muscle than by rational analysis.

Another problem for Australian bureaucracies is I believe the over-emphasis on what is described as the notion of "preference for relevance". This may often have unfortunate consequences in terms of the quality of management and it manifests itself in various ways. For example, it has been the tradition in Australia for departments dealing directly or indirectly with economic issues to be staffed overwhelmingly by officers with basic tertiary qualifications in economics. This compounds the problem of ethos to which I have already referred. By diminishing the variety of discipline, training and experience it narrows the overall departmental view of the world. It seems to me that we should remind ourselves that one with a degree in economics is not necessarily an economist - any more than, as a history graduate, I am an historian. At best, one can only assume that the economics graduate has acquired some reasonable degree of intellectual discipline and some reasonable grasp of the basic concepts associated with that discipline. Besides, as a proximate policy-maker, the issues with which he is confronted - certainly as he is elevated in the hierarchy - will be handled less by reference to accumulated academic knowledge and more by virtue of less tangible attributes such as judgment and common-sense and analytical capacities which are the preserve of no particular kind of graduate.

In recruitment to departments and authorities concerned with socio-economic policy formulation, the overriding criteria should surely be intellectual capacity, along with those other attributes to which I have already referred. Special expertise - in economics or anything else - may be required (or hired on an ad hoc basis) to meet the particular needs of the particular department but we should not delude ourselves that a basic degree is representative of specialist expertise.

In terms of broader management - about which I will make further observations later in this paper - the notion of preference for relevance may often lead to skewed management and myopic policy making. It may be helpful for the Head of a particular department or authority to have expertise in the relevant area but only if he is also a good manager. In big Government, the quality of management is fundamental to the quality of policy output and it should not necessarily follow that a diplomat is necessarily the person best equipped to head the Department of Foreign Affairs, or a teacher the Department of Education, or a doctor the Department of Health, or an agricultural scientist the Department of Agriculture. Extension of this thesis into the private sector would suggest that a geologist or mining engineer should necessarily be the head of CRA or that a pilot should necessarily be the executive head of an airline or a pharmacist the head of a drug company. For preference for relevance to be taken to this extreme - as has so often been the case in the public sector - is a nonsense. There are examples of excellent specialist administrators and of appalling generalist administrators. There are also examples of the reverse. The key point surely is that

the head of a department in big Government - like the head of a large enterprise in the private sector - should be chosen primarily for his skills in management and policy formulation.

REFORM AND REFORMERS

It is only two or three years since the Coombs Report was the most topical document in Australia on public service reform. It is a useful starting point for discussion of reform.

First, however, I would like to canvass some of the negative aspects as I see them. I think the terms of reference were too wide and that it was unfortunate that they were interpreted accordingly. The report is too big, too indigestible, too cluttered with hundreds of minor recommendations. It is a blank cheque for confusion and resistance. Attention on the fundamental is constantly diverted by the Commission's forays into minutiae. The approach is too much that of the blunderbuss; too little that of the rifle. I also believe that the membership of the Royal Commission was deficient in a number of respects but most notable because of the absence of a direct representative of users of the public service - whether those "users" be from commerce or welfare recipients. I believe, further, that too much time and money was spent on consultants, academic and otherwise, to produce esoteric theses on all sorts of issues marginal to what I regard as being the central issues of responsibility, accountability and professional management.

Weller and Smith (1977) in discussing relationships between the Commission and the Public Service, tell us that the Commission " ... had to try to square the circle and combine co-operation with incisive questioning." The Commission's overall task would, in my view, have been rendered easier had it not also tried to re-invent the wheel! As an aside, one must also observe with relief that their questioning was incisive.

I believe that the issues of responsibility, accountability and management should have been the prime focus of the report - by a Royal Commission or Parliamentary Committee - with the detail being pursued on a planned and continuing basis by small task forces (including outsiders) working with, and within, the Service. It is in this latter context that specialist studies would have been more appropriate.

For all this, however - for all the deficiencies and while the Report may have resulted to date in more Ph.D's and book royalties than substantive implementation - it is nonetheless an immensely valuable document. It is valuable as a source document and in its prescriptions - the major problems are aired, along with the solutions seen as desirable by the Commission.

Certainly, as a practitioner, I am more comfortable with the Royal Commission's prescriptions than with those of some others. Dror (1978, Ch. 16) for example, canvasses a rash of improvements he perceives as being needed in the area of public policy-making - more metapolicy-making (ie. more knowledge about the process itself), more learning feedback, more systematic determining of strategies and goals, more searching for alternatives, more development of rational and extrarational components, more knowledge, more equipment, more energy - more everything. Among his many suggestions there are some that are - in his own words - "realistically idealistic"; others that may be unrealistically idealistic; and some that are plain commonsense and the subject of ready application. However, while his thesis provides us with a useful analytical model, it seems to me to reveal an overemphasis on structural change and a pre-occupation with the seemingly arbitrary allocation of various intangible factors that are not rendered more tangible by being popped into Dror's tables and charts. One emerges from a reading of his work wondering what one's number should be!

The recommendations of the Royal Commission to which I would like to make particular reference are those that relate to responsibility, accountability and management. I shall also refer to the matter of public participation in the policy-making process.

The approach adopted by the Royal Commission in relation to ministerial responsibility and bureaucratic accountability was to advance a network of recommendations which, taken together, seek to serve the twin aims of clarifying and strengthening the Minister's authority in relation to his department and of strengthening the accountability and managerial freedom of the permanent head. The major recommendations in this context include proposed amendments to the Public Service Act to incorporate direct references to the responsibility of the departmental head; the proposals for triennial, rolling forward estimates, with associated goals, objectives and priorities; the introduction of efficiency audits; a cautious approach to the creation of statutory authorities; the regular submission of annual reports; the rotation of officers between policy and management areas; and the rotation of, and improved selection procedures for, permanent heads.

The Commission attached particular importance to its proposals regarding forward estimates which it saw as a vehicle for the effective co-ordination of manpower, money, priorities and programmes. It was also seen as the best way of bridging the gap between political objectives and executive achievement.

These are sensible proposals which, with sound management, should mostly be capable of fairly ready implementation. However, there can be many a slip twixt the good sense of the proposals and the reality of implementation. Besides, one can reasonably ask whether you can in fact "make a silk purse out of a sow's ear." Do Ministers want the predictability and the planning and the more ordered responsibilities inherent in the Coombs proposals? Or might they feel more comfortable in the old system with its advantages of options being kept open and of Ministers perhaps being able to claim authority and responsibility without necessarily exercising it? There is the added question as to whether - particularly with three year Parliaments - politicians want to plan beyond the next election. Indeed, is it possible effectively to do so, given the reality of the political environment?

The recommendations may find their way on to the statute books and into the performance of everyday executive activity. However, one suspects that, in the ultimate, the issues of responsibility and accountability may well rest more on the vigilance of Parliament and of outsiders than on structural and legislative refinements. The further development of Parliamentary Committee arrangements will serve this end. In this context, the establishment of the Senate Estimates Committees at Federal level was a positive step forward.

Given the temper of the times, it is perhaps not surprising that social change, and its consequences for the bureaucracy, should emerge as a major theme in the Coombs Report. The Commission thus saw a key thrust of the report being directed towards making the bureaucracy more responsive and more sensitive; more accessible to members of the public and to client groups; more representative in structure and personnel of the society which it is supposed to serve; more open and less hierarchial. In other words, the report is talking about bureaucracy being, or being made, more contemporary.

To these ends, there was a further package of recommendations. The proposals in this context related to improved service delivery, including the fixing of specific decision-making powers on counter-staff; more delegation to field officers; various measures for inter-departmental co-ordination at the regional level; broader representation on advisory bodies; better information services; and so on. I believe the Commission was somewhat tentative in canvassing the implementation of some of these lofty and commendable proposals.

Related to these proposals were others which canvassed such matters as open reporting on staff; exchange schemes between the Public Service and other occupations; more mobility within the Public Service; and the need to reduce inbreeding in certain areas, notably the Departments of the Treasury and Foreign Affairs. A related recommendation was for the establishment of a Department of Industry and the Economy which, in the event, was rejected in lieu of other changes, including the splitting of the Treasury into the

Treasury and Finance Departments and the expansion of the role of the Prime Minister's Department.

Because it was the subject of considerable attention by the Royal Commission - and remains a topical issue at both State and Federal levels - it is appropriate to make some observations about public participation in the policy-making process. Besides, the subject is directly relevant to my thesis - that of the need for reform that focuses on the quality of bureaucratic input to the policy-making process - if only because to accommodate the demand for greater public participation in the process must inevitably place greater demands on the proximate policy-makers.

The notion of public participation is a commendable one although it is perhaps arguable as to how widely such participation is in fact demanded. It seems to me that it is something which needs to be kept in its proper perspective. It may merely mean pandering to those who make the most noise and, importantly, public participation needs to be managed, administered and interpreted - a subject of policy-making in its own right. When conservationists demand participation in decision-making on power development in Tasmania their demand may be entirely legitimate but I am not sure that they are necessarily having an attack of altruistic pluralism. They mean surely that they want a say in the matter - not boiler-makers or pensioners or shopkeepers or members of the Royal Society but themselves, conservationists.

Government is, I believe, correct in promoting the notion of public participation but it is one thing to grab the tail; quite another to control the tiger. Unless you approach this question of public participation with great care, problems of equity in policy making may well be compounded rather than alleviated. For example, a public opinion poll, commissioned by conservationists, may reveal that a majority of people do not want the Franklin/Lower Gordon area flooded for power development. The fact that the same people were not asked if they would be prepared to pay substantially more for their electricity may be overlooked by the busy politician unless he is supported by competent professional advisors. As the staff of the Royal Commission pointed out: (Hazelhurst, C. and Nethercote, J.R. p. 186 in R.A.C.A.G.A.) "In the end the official must be guided by the weight his Minister attaches to various forms of participation, but in turn it should be recognised that in making a judgment the Minister will be influenced by departmental advice and that, in practice, much will be left to decisions by officials themselves."

So, we are reduced again to considerations of bureaucratic professionalism - to the need to sift and interpret and analyse and collate and, above all, to distil the complex into some balanced and digestible form. And all that is to be undertaken by people; by fallible human beings. It is art rather than science and it reveals again the importance of the bureaucrat in policy making. This role is the more sensitive in a situation in which, as Payne (1976, p. 311) reminds us, " ... the planning process is concerned with power and, as such, the participation of certain groups of society has come to take precedence over others almost to their total exclusion." Payne may have been writing about public participation in relation to urban planning but this observation is no less relevant when applied to other areas of policy making.

CONCLUSION

I believe that changes to structures can be important, very important. So, too, will improved arrangements for the collection, dissemination and use of information be important. Public access to the process is important, too. So is the need for appropriate and contemporary legislation to buttress such principles as responsibility and accountability. All these things are indeed important. For my part, however, they are nothing if the basic thrust of any reform is not people. I am not suggesting that Coombs ignored this factor - he paid it close attention. I am merely asserting its overriding importance. The recruitment, training, counselling, encouragement, mobility, secondment, terms and conditions of and for people is quite fundamental - to enhance their contribution as individuals, not as numbers; to elevate the quality of policy-making by

democratic officials responsible to democratic Government in a democratic society.

Regarding recruitment, I am aware of countless examples of people with brilliant academic records proving to be inept as administrators and as policy analysts. Regarding training, I am familiar with countless examples of those assigned to training courses being those who can "be spared," rather than those in most need of further training. This is a particular problem at the senior management level - too many senior officers simply do not recognise who needs training, including themselves. Indeed, insufficient attention is given to post-recruitment training in most Australian bureaucracies. Regarding conselling, I am familiar with examples of officers being denied promotion for reasons which have never been conveyed to them and yet the "problems" were mostly readily soluble. Regarding secondment - for example, to the private sector - recent experiments in this area at Commonwealth level are to be welcomed. Continuation and expansion of this approach may serve, over time, to alleviate the problems associated with Canberra's physical isolation. (In public policy terms, Canberra is akin to Whitehall on the Isle of Man!)

It is against this background that I would also like to make passing reference to a long held personal aspiration - that we will one day have a national administrative, or public affairs, staff college. As a joint venture by all three levels of Government it would draw on a permanent staff and on experts from all fields in offering a wide range of courses for people at all levels in many bureaucracies. It might achieve many things but, in particular, it would offer a change of diet for bureaucrats who need to see their role in its broadest context. It might also help to break down the elements of confrontation seemingly inherent between bureaucracies in a Federal system.

The precision and predictability of bureaucratic reform will surely always be influenced by the idiosyncrasies of people - people as both the tool and the target of reform. Reformers - appointed or self-appointed - will be people carrying their own particular package of values, passions and prejudices. So, too, will the bureaucrats. One is reminded of Isiah Berlin's (1957) essay on Tolstoy and history, "The Hedgehog and the Fox." According to Berlin, Tolstoy's concern was with " ... that which alone is genuine, the individual experience, the specific relation of individuals to one another ... the rare flashes of insight, the ordinary day-to-day succession of private data which constitute all there is - which are reality."

One could apply the same sentiments to bureaucracy and bureaucratic reform. The considerations of which Berlin wrote - those basic human considerations - are at once the life-blood of a democratic bureaucracy and yet, too, they are the rock on which reform may so often founder. This is not to say that reform is doomed to failure - merely that the pinnacle will never be scaled. It will only come closer - whatever the particular perception of the particular reformer - and then recede again in the mists of new values and new technologies. And yet to tackle the pinnacle is still important - not simply because it is there but, given the inevitable ossification of institutions, because bureaucratic change must be the subject of constant direct attention. The staff summary of the Coombs Report (Hazelhurst and Nethercote in R.A.C.A.G.A. p. 175) addresses this point in the following terms: "If the spirit of our recommendations infuses the attitudes of officials, adaptation is more likely to become a continuous, self-generating process. It would not, however, be wise to rely wholly on such internal sources of self-criticism and adaptability. External stimulus is from time to time necessary, as is the 'lateral thinking' of persons with wide but difference experience."

To assume that our bureaucracies will change in line with broader social change without such constant attention is, I believe, likely to widen the gap between following change and truly reflecting such change as soon as it can prudently be arranged. And that is to speak from the viewpoint of more formal or "organised" reform. Reform of a more fundamental variety might occur in a variety of ways but it should occur, perhaps most of all, through our educational institutions which hold the key to disseminating a better, longer-term understanding of our political and administrative institutions. (I believe, however, that there is presently a considerable deficiency in this latter area.

"Government" - with all that the word means - does not in my view receive sufficient attention in secondary school teaching programmes.)

In other words, continuing reform of a positive and fundamental kind will occur in tandem with the progressive elevation of the political consciousness of the community at large.

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NEW TASMANIAN SPIDERS OF THE FAMILIES ARCHAEIDAE, CYCLOCTENIDAE, AMAUROBIIDAE AND MICROPHOLCOMMATIDAE

by V. V. Hickman
Hobart

(with 33 text-figures)

ABSTRACT

HICKMAN, V.V., 1981 (30 ix): New Tasmanian spiders of the families Archaeidae, Cycloctenidae, Amaurobiidae and Micropholcommatidae. *Pap. Proc. R. Soc. Tasm.*, 115, 47-68 (with 33 figures). ISSN 0080-4703. New Town, Hobart, Tasmania, Australia.

Of the seven new species described one, *Zearchaea globosa*, belongs to the family Archaeidae and one, *Otira affinis*, to the family Amaurobiidae. Both are placed in genera hitherto recorded from New Zealand. Four are placed in the family Cycloctenidae not previously recorded from Tasmania. They belong to the genus *Cycloctenus* recorded from New Zealand, New South Wales and Lord Howe Island. A key to the genus is given. A new species in the family Micropholcommatidae is added to the four already known to occur in Tasmania.

INTRODUCTION

The spiders described in the present paper include two species closely related to the New Zealand genera *Zearchaea* and *Otira*. They were collected in rain-forests of south-western Tasmania. They are of some interest from the distributional point of view. The family Cycloctenidae, which is represented by four new species, has not been recorded previously from Tasmania.

Family ARCHAEIDAE

The family Archaeidae is one of the smaller groups of spiders. It was established on three fossil species from Baltic amber by Koch and Berendt (1854). After a lapse of nearly 100 years Petrunkevitch (1950) remarked that there were more fossil species recorded in the family than there were living species from regions where the Archaeidae were known to occur. At the present time about 30 species, including fossils, are recorded. They have a very wide distribution, being described from South Africa, Madagascar, Australia, New Zealand and Patagonia. Lehtinen (1967) considered that the genera *Zearchaea*, *Pararchaea* and *Holarchaea*, which occur mainly in New Zealand (Forster 1955) and Tasmania (Hickman 1969) have more affinity with the Patagonian genus *Mecysmaucheniius* Simon (1884) and should form with it a separate family the Mecysmaucheniidae. The matter is one of difference of opinion (Legendre 1970).

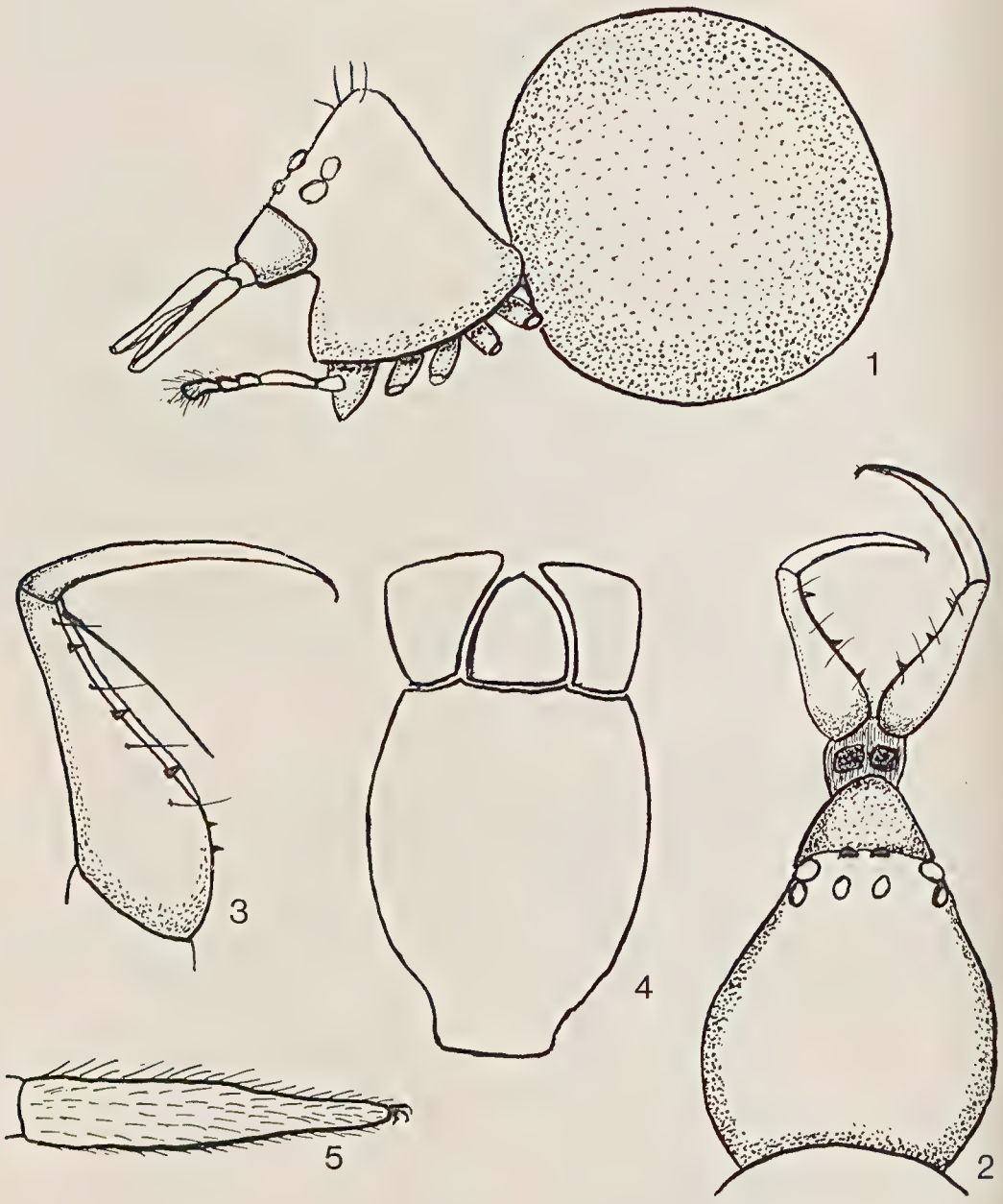
Genus *Zearchaea* Wilton, 1946

Zearchaea globosa n. sp.

Female

Measurements in mm:-

Body length	1.40
Carapace length	0.63
Carapace width	0.46
Abdomen length	0.88
Abdomen width	0.84



FIGS 1-5.- *Zearchaea globosa* n. sp. Female: 1-body, 2-carapace and chelicerae, 3-chelicera, 4-maxillae, labium and sternum, 5-tarsus of a leg.

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0.64	0.17	0.46	0.21	0.35	1.83
2	0.45	0.17	0.34	0.21	0.28	1.45
3	0.41	0.12	0.32	0.22	0.25	1.32
4	0.56	0.17	0.42	0.22	0.34	1.71
Palp	0.21	0.04	0.07	-	0.08	0.40

Colour of carapace, maxillae, labium, sternum and abdomen dark brown. Legs and chelicerae yellowish brown; palpi yellowish brown with dark tibia and tarsus.

Carapace (fig. 1) higher than long but not as high as abdomen, sloping steeply down in front and behind, without a constriction to form a "neck". Clypeus sloping to the front and forming a blunt point above the base of chelicerae. Eyes eight, in two recurved rows. Ratio of eyes AME:ALE:PME:PLE = 3:6:5:5. Median ocular quadrangle longer than wide in ratio 5:4 and wider behind than in front in ratio 5:3. Lateral eyes contiguous. AME separated by 2/3 their diameter. PME separated by 3/5 their diameter. Surface of carapace without tubercles but clothed with a few short hairs.

Chelicerae (figs 2 and 3) long and slender; widest in basal half. Articular membrane joining them to the cephalothorax has a pair of sclerites above and below. Each paturon is 0.28 mm long and 0.10 mm in greatest width. Fang 0.22 mm long with tip curved to form a hook. Margins of furrow minutely serrate. Promargin with three teeth; retromargin with two smaller teeth near base. A long slender spine arises near base of fang and projects for about three-quarters of the furrow's length (fig.3).

Maxillae (fig.4) converging in front of labium; anterior margin almost transverse and provided with a serrula, a few curved hairs and a weak scopula at inner angle.

Labium longer than wide and almost as long as the maxillae.

Sternum long shield-shaped; longer than wide in ratio 5:4; truncate behind; surface slightly convex and furnished with a few short hairs.

Palp about as long as femur of third leg. Tarsus short and thick, provided with many hairs. Claw absent.

Legs in order of length 1.4.2.3. Lightly clothed with short hairs; spines absent. Three trichobothria on first tibia, one on second, two on third and three on fourth; elsewhere none. Tarsi of first and second legs taper to a thin apex in distal third (fig.5). Claws three. They appear to have an onychium and no teeth.

Abdomen globose, without tubercles or sclerites, thickly covered with fine short hair. Epigynum indistinct. Six short spinnerets and a colulus present.

Locality:- Strathgordon, southwestern Tasmania; 1 ♀ (holotype). 25.4.1978. J.L. Hickman.
Remarks:- The specimen of *Zearchaea globosa* was found among moss in dense rain-forest. It was the only specimen of the species in a collection of 7 300 spiders from southwestern Tasmania. Most of the collection was obtained from moss and leaf litter by the aid of Berlese funnels. The single specimen of *Z. globosa* was preserved intact and hence some features could not be ascertained. However, the form of the carapace, the unusual shape of the clypeus, the arrangement of the eyes, tibiae of the first legs much longer than metatarsi are all characters shared with the type of the genus *Zearchaea*, namely *Z. clypeata* Wilton, which occurs in New Zealand.

New Tasmanian Spiders

Family CYCLOCTENIDAE

The genus *Cycloctenus* L. Koch (1878) contains only seven described species. These have been recorded from three localities; two from Australia, four from New Zealand and one from Lord Howe Island. None has been recorded from Tasmania. The genus has been placed in several different families, namely, the Ctenidae by L. Koch (1878), Lycosidae by Simon (1898), Toxopidae by Forster (1964) and tentatively in a new family, Cycloctenidae, by Lehtinen (1967).

The four new species described herein have all the characters of the genus *Cycloctenus* as defined by L. Koch (1878) including the ventral rows of spines on the tibiae and metatarsi of the first pair of legs. However, Lehtinen (1967, p.371, Table 40) listing the characters of the family Cycloctenidae states that these spines are "absent" and that members of the family carry their egg-sacs. *Cycloctenus cryptophilus* n. sp. from Tasmania and *Cycloctenus fugax* Goyen (1890) from New Zealand make lenticular egg-sacs, which they do not carry, but attach to a stone or log and then camouflage with particles of debris. In spite of these differences the Tasmanian species of *Cycloctenus* have most of the characters which Lehtinen lists and are better placed in the family Cycloctenidae than in any of the previous families to which the genus was assigned.

The following key to the genus is given:-

Key to the genus *Cycloctenus*

1	First and third legs equal in length	2
	First leg longer than third	3
2(1)	Body length 6.5 mm	....*C. abyssinus* Urquhart
	Body length 10.5 mm	....*C. pulcher* Urquhart
3(1)	AME as large as PLE	....*C. vittatus* Rainbow
	AME smaller than PLE	4
4(3)	Chelicera with 4 promarginal teeth	....*C. fugax* Goyen
	Chelicera with less than 4 promarginal teeth	5
5(4)	Chelicera with 3 promarginal teeth	....*C. flaviceps* Koch
	Chelicera with 2 promarginal teeth	6
6(5)	Chelicera with 5 retromarginal teeth	....*C. westlandicus* Forster
	Chelicera with 2 retromarginal teeth	7
7(6)	PLE larger than PME	8
	PLE smaller than PME	9
8(7)	AME larger than ALE	....*C. cryptophilus* n. sp.
	AME smaller than ALE	....*C. infrequens* n. sp.
9(7)	Second leg longer than third	....*C. flavus* n. sp.
	Second leg not longer than third	....*C. montivagus* n. sp.

Genus *Cycloctenus* L. Koch (1878)

Cycloctenus flavus n. sp.

Male

Measurements in mm:-

Body length	5.83
Carapace length	3.08
Carapace width	2.23
Abdomen length	2.85
Abdomen width	1.83

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	2.28	1.03	2.17	2.34	0.91	8.73
2	2.06	0.91	1.88	2.06	0.91	7.82
3	2.06	0.91	1.37	1.88	0.86	7.08
4	2.40	0.97	1.83	2.57	1.14	8.91
Palp	1.14	0.57	0.57	-	1.26	3.54

Colour of carapace yellow with two brown bands extending from posterior lateral eyes to hind margin. Side margins edged with brown. Chelicerae, maxillae, labium, sternum, palpi and legs yellow. Transverse brown bands below femora. Abdomen above cream with six pairs of dark dots forming a double median row on front half. On each side of the row of dots a broken dark brown band extends from front to hind end. Sides of abdomen mottled with brown. Ventral side cream with a median brown band.

Shape of carapace as in fig. 6. Highest part with a well marked longitudinal fovea. Eyes in three rows; first row formed by small AME, second by large PME and small ALE, third by large PLE. The length ratio of the three rows 21:58:72. Ratio of eyes AME:ALE: PME:PLE = 9:7:17:15. The AME are separated by once their diameter. The PME separated from each other by once their diameter and from ALE by 5/17 of their diameter. The PLE are separated from each other by four times their diameter and from PME by once their diameter. The trapezium formed by the posterior eyes is wider behind than it is long in the ratio 72:43. Height of clypeus about equal to diameter of AME. Surface of carapace clothed with fine, short, recumbent hairs. A few yellow setae are present in ocular area.

Chelicerae (fig.7) conical, geniculate and slightly inclined to maxillae. Lateral condyles well developed. Fang curved. Each margin of furrow with two teeth. A few minute denticles in furrow itself. On each side near base of fang is a long barbed hair.

Maxillae parallel, longer than wide in ratio 10:7, lightly clothed with erect hairs, serrula present and a scopula at inner apical angle.

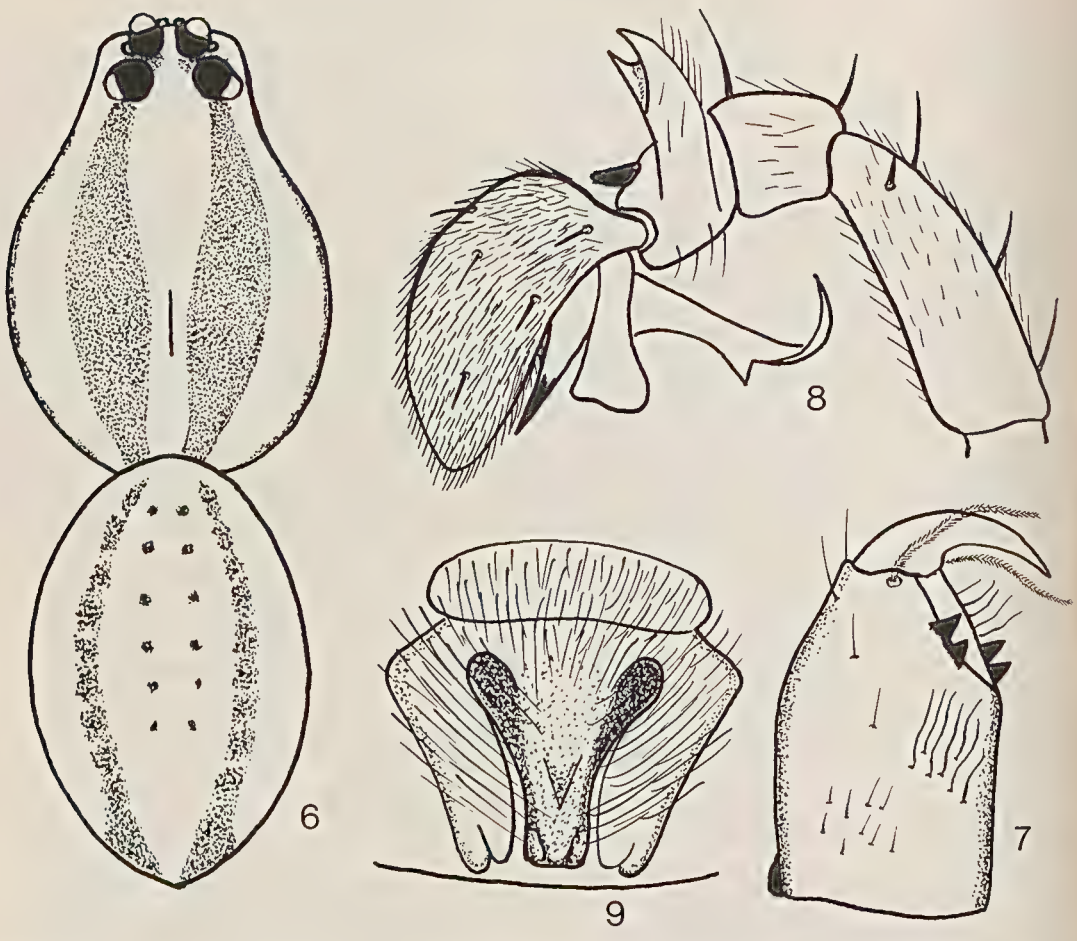
Labium wider than long in ratio 7:5, not extending beyond half length of maxillae, truncate in front and with lateral excavations at base.

Sternum shield-shape, as wide as long, slightly emarginate behind labium and lightly clothed with erect hairs.

Legs in length order 4.1.2.3. Trichobothria in a double row of about six on each tibia, a single row of four on each metatarsus and a single row of three to five on each tarsus. Trochanters not notched. Three tarsal claws; upper claws with nine teeth, lower claw with two. No claw tufts present.

Spines: *First leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral 0. Patella dorsal 1-1, prolateral 1, retrolateral 1, ventral 0. Tibia dorsal 0-1-2, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 1-1-0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2. Tarsus 0. *Second leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral 0. Patella dorsal 1-1, prolateral 1, retrolateral 1, ventral 0. Tibia dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Other segments as in first leg. *Third leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral. Patella dorsal 1-1, prolateral 1, retrolateral 1, ventral 0. Tibia dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2. Metatarsus dorsal 1-1-0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-1. Tarsus 0. *Fourth leg*. Same as third leg.

Palpi (fig.8) slightly longer than carapace. Tibia with a large erect apophysis, which arises dorsolaterally on the prolateral side. Distal end of the apophysis is bifurcate forming two sharp points. On retrolateral side of tibia is a short black apical projection. On dorsal side of tarsus are several spines mingled with a dense clothing of hair. Genital bulb has a very large median apophysis, which is produced into a fine



FIGS 6-9.- *Cycloctenus flavus* n. sp. Male: 6-body, 7-retrolateral side of chelicera, 8-palp. Female: 9-epigynum.

curved tip and directed inwards on the prolateral side. Half way along the apophysis is a small pointed barb.

Abdomen oval, clothed with fine hairs and a few bristles. Six spinnerets, short and conical, anterior pair larger than others. A colulus clothed with long hairs is present. Tracheal spiracle is close in front of colulus and leads into four tracheal tubes, which are confined to abdomen. Book lungs normal.

Female

Measurments in mm:-

Body length	6.63
Carapace length	2.87
Carapace width	2.24
Abdomen length	3.77
Abdomen width	2.80

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	2.00	1.09	2.00	1.88	0.80	7.77
2	2.06	1.03	1.66	1.77	0.80	7.32
3	1.88	1.03	1.20	1.66	0.74	6.51
4	2.28	1.03	1.66	2.34	0.97	8.28
Palp	0.97	0.46	0.57	-	1.14	3.14

Colour resembles that of male. The form of the carapace, eyes, chelicerae, maxillae, labium and sternum are also as in the male.

Legs in order of length 4.1.2.3, slightly shorter than those of male.

Spines: *First leg*. Same as in male except the metatarsus has 2-1-1-2 dorsal spines. *Second leg*. Same as in male except tibia has 0-1-2 dorsal spines and the metatarsus 2-2-1p-2 dorsal spines. *Third leg*. As in male except tibia has 0-1-1 and metatarsus 2-2-2 dorsal spines. *Fourth leg*. As in male except tibia has 0-1-1 dorsal, 2-1p-2 ventral and the metatarsus 2-2-2 dorsal spines.

Palpi slightly longer than carapace. Spines as follow:- Femur dorsal 1-1-1, prolateral 0-0-1, retrolateral 0, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 0-1, ventral 0. Tarsus dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-3. Five trichobothria on tibia and three on tarsus. Tarsal claw with five teeth.

Abdomen oval, clothed with fine hair and bristles as in male. Epigynum (fig.9) wider than long. The median septum V-shaped and truncate posteriorly. On each side a sclerotized plate with a curved inner margin close to the septum.

Locality:- Tarraleah, Tasmania. 1 ♂ (holotype), 1 ♀ (paratype), 7.10.1957. V.V. HIckman, southwestern Tasmania. 20 ♀♀ and 190 immature specimens Jan.-March 1976, 1977, 1978, C. Howard, C. Johnson and L. Hill.

Remarks:- Specimens were collected in moss, and leaf litter in rain-forest areas.

Cycloctenus montivagus n. sp.

Female

Measurements in mm:-

Body length	9.16
Carapace length	4.05
Carapace width	2.97
Abdomen length	5.14
Abdomen width	3.77

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	3.08	1.43	2.68	2.46	1.26	10.91
2	2.91	1.37	2.28	2.51	1.20	10.27
3	2.86	1.43	2.06	2.80	1.26	10.41
4	3.54	1.43	2.86	4.00	1.60	13.43
Palp	1.26	0.69	0.86	-	1.26	4.07

Carapace light brown edged with dark brown round lateral margins. A thick dark median line extends from ocular region to fovea. An irregular dark brown band on each side runs back from posterior lateral eyes to hind margin. The band is crossed by darker radial marks (Fig.10). Chelicerae, maxillae and labium light brown, sternum darker. Legs and palpi light brown with transverse dark bands partly surrounding femora, patellae and tibiae. Abdomen above light brown with blotches and streaks of dark brown tending to form a pattern (fig.10). Ventral surface yellowish brown speckled with dark brown. Epigynum brown. Spinnerets yellowish.

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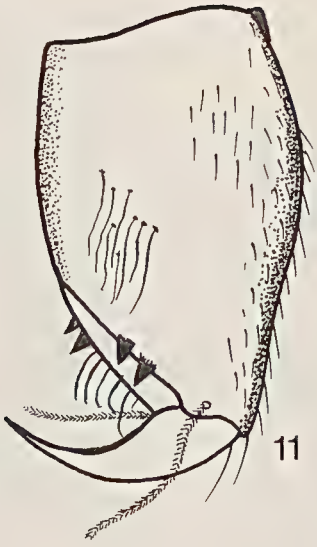

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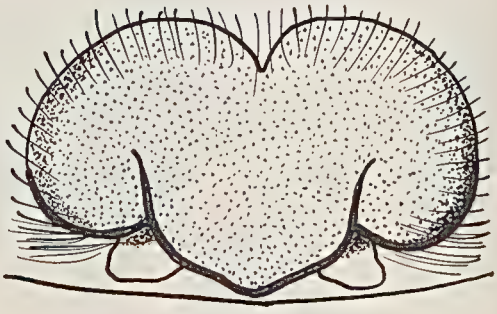

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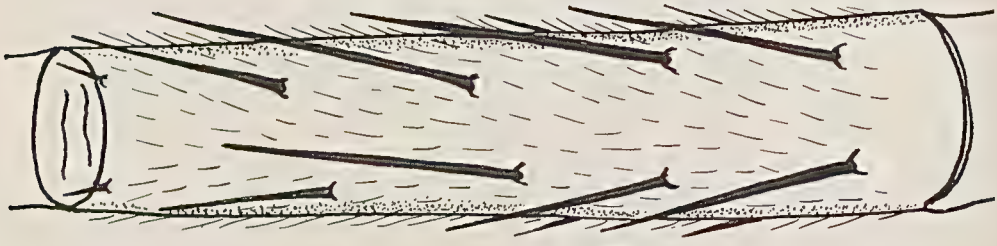

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FIGS 10-13.- *Cycloctenus montivagus* n. sp. Female: 10-body, 11-retrolateral side of chelicera, 12-ventral side of first tibia, 13-epigynum.

Shape of carapace oval, narrowed in front, widest between second and third coxae, highest at each side of fovea, which is deep and longitudinal. Surface of carapace clothed with short recumbent hairs; a few bristles in ocular region. Eight eyes disposed in three rows. The first row formed by the AME, the second by ALE and PME and the third by PLE. The length of the rows are in ratio 5:16:20. The eyes are mounted on thick black rims. Ratio of eyes AME:ALE:PME:PLE = 7:9:30:20. The AME are separated from each other by 11/7 of their diameter. PME separated from each other by half their diameter and from ALE by 1/6 of their diameter. PLE are separated from each other by 18/5 of their diameter and from PME by 11/10 of their diameter. The quadrangle formed by the PME and PLE is about 3/5 as long as its posterior width.

Chelicerae conical with large lateral condyles; sparsely clothed with short hairs in front. Fang curved. Furrow with two teeth on each margin (fig.11).

Labium wider than long in ratio 9:7, extending to about half the length of maxillae; truncate in front with small lateral excavations at the base.

Maxillae parallel, longer than wide in ratio 7:5. Scopula present on inner apical angle and a few erect hairs on surface.

Sternum shield-shaped and longer than wide in ratio 29:25, ending in a point between hind coxae, slightly emarginate at base of labium, lightly furnished with erect hairs.

Legs in order of length 4.1.3.2. On the ventral side of the tibiae of the first and second legs are five pairs of long spines (fig. 12). Four trichobothria are present in a single row on each tarsus and metatarsus, and about six in a double row on each tibia. Three tarsal claws are present; upper claws with 10 teeth, lower claw with two. Claw tufts absent. Trochanters slightly emarginate.

Spines. *First leg*. Femur dorsal 1-1-1, prolateral 0-0-1-1, retrolateral 0-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 0, prolateral 1-1-0, retrolateral 1-1-0, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 0-0-1, retrolateral 0-0-1, ventral 2-2-2-2. Tarsus 0. *Second leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Other segments as in first leg. *Third leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2. Metatarsus dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-3. Tarsus 0. *Fourth leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 0-0-1, ventral 0. Other segments as in third leg.

Palpi slightly longer than carapace. Spines disposed as follows: Femur dorsal 1-1-2, elsewhere 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 0, ventral 0. Tarsus dorsal 1-0-0, prolateral 1-1, retrolateral 1-1, ventral 2-2-1-3. Claw very slightly curved and with five teeth.

Abdomen oval, clothed with fine recumbent hairs mingled with coarse erect hairs or bristles. Epigynum (fig. 13) wider than long in ratio 19:12, with a broad septum, a median notch in the anterior margin and a rounded lobe on each side. Spinnerets short and conical, anterior larger than others with the second segment sunken in the apex of the first segment. A short colulus is present.

Locality:- Mount Wellington, Tasmania. 1 ♀ (holotype) 31.1.1940. V.V. Hickman.

Remarks:- Only the one specimen was found. It was taken on the summit of the mountain amongst leaf litter under *Richea scoparia*.

Cycloctenus cryptophilus n. sp.

Male

Measurements in mm:-

Body length	8.50
Carapace length	4.50
Carapace width	3.10
Abdomen length	4.00
Abdomen width	2.70

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	5.55	2.00	5.75	6.65	2.50	22.45
2	5.55	2.10	5.70	6.50	3.00	22.85
3	5.00	1.75	4.50	6.50	2.75	20.50
4	5.55	1.90	5.50	7.50	3.25	23.70
Palp	2.50	0.85	0.70	-	1.75	5.80

Carapace, chelicerae, legs and palps mainly light brown, the legs spotted and blotched with dark brown. Maxillae and labium brown. Sternum and coxae yellowish brown, the sternum speckled with dark brown towards margin. Abdomen above light brown with a median pattern of dark brown as in fig.14. Sides dark brown, ventral surface light brown speckled with dark brown. Spinnerets yellow.

Shape of carapace broadly oval, narrowed in front, depressed between head region and fovea, which is deep and longitudinal. Eyes eight disposed in three rows, first row formed by AME, second by ALE and PME and the third by PLE. Ratio of eyes AME:ALE:PME: PLE = 9:8:11:12. The median ocular quadrangle wider behind than in front in ratio 3:2 and its length equal to its width behind. Clypeus little higher than diameter AME and sloping slightly to front. All the eyes mounted on large black rims.

Chelicerae conical, condyles well developed, fang well curved, furrow oblique with two teeth on each margin. Each paturon geniculate and close below the "knee" has a conspicuous pair of spines, which cross the pair on the opposite paturon (fig.15).

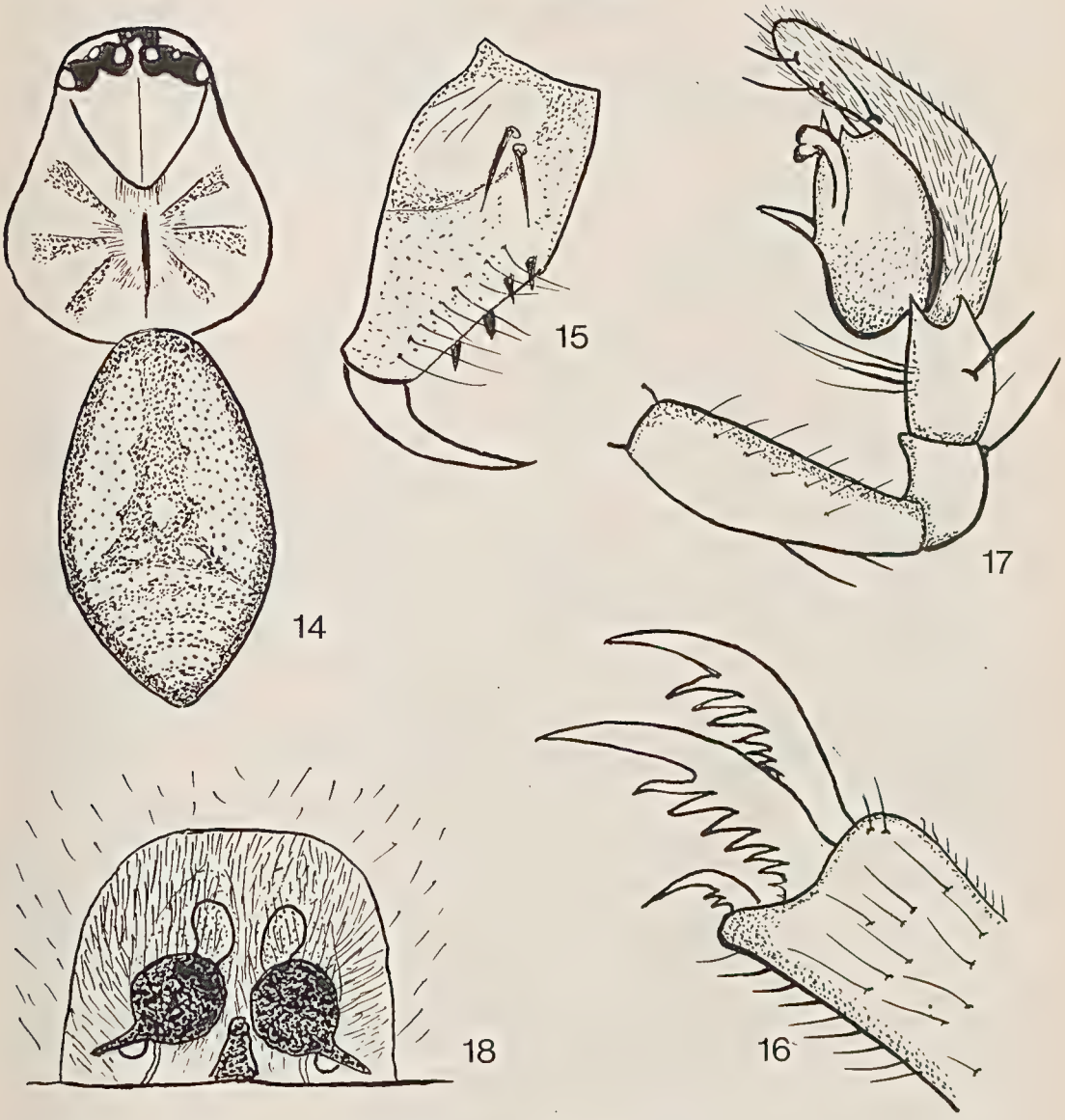
Maxillae almost parallel, longer than wide in ratio 15:8, provided with serrula and scopula.

Labium about half the length of maxillae, little longer than wide in ratio 15:14. Truncate and slightly excavated in front. Small lateral excavations on each side at base.

Sternum as wide as long, almost truncate in front, pointed between hind coxae. Slightly convex and sparsely clothed with erect hairs.

Legs in order of length 4.2.1.3; clothed with fine hair which is coarser below tarsi than elsewhere. Trichobothria are present in a double row on tibiae and metatarsi and a single row on tarsi; they have very small bases and are difficult to see; three tarsal claws are present, upper claws with about eight teeth, lower claw with two very small teeth. No claw tufts are present (fig.16).

Spines. *First leg.* Femur dorsal 1-1-1, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1-1-1, retrolateral 1-1-1-1-1, ventral 2-2-2. Tarsus 0. *Second leg.* Femur dorsal 1-1-1, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1-1-1, retrolateral 1-1-1, ventral 2-2-2. Tarsus 0. *Third leg.* Femur dorsal 1-1-1, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 0. Patella 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1-1, ventral 2-2-2. Metatarsus dorsal 1, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-0-0. Tarsus 0.



FIGS 14-18.- *Cycloctenus cryptophilus* n. sp. Male: 14-body, 15-prolateral side of chelicera, 16-tarsal claws, 17-palp. Female: 18-epigynum.

Fourth leg. Femur dorsal 1-1-1, prolateral 1-1-1-1, retrolateral 0-1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2. Metatarsus dorsal 0, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-2-2-2. Tarsus 0.

Palp (fig.17) densely clothed with hair on dorsal side of tarsus, elsewhere sparsely clothed. Spines on dorsal side of femur 1-1, patella 1, tibia 1 and tarsus with three

or four on distal half. Tibia with two short apophyses on retrolateral side at apex. One trichobothrium on dorsal side. Genital bulb as in figure 17.

Abdomen long oval. Dorsal pattern variable and sometimes with a large yellowish area behind the dark central area. Six spinnerets, anterior pair largest. Colulus and tracheal spiracle present.

Female

Measurements in mm:-

Body length	14.25
Carapace length	5.55
Carapace width	4.50
Abdomen length	8.75
Abdomen width	6.25

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	5.75	2.50	4.70	4.85	2.00	19.80
2	5.10	2.50	5.00	5.00	2.00	19.60
3	4.80	2.00	3.90	5.05	2.20	17.95
4	5.75	2.00	4.50	6.25	2.75	21.25
Palp	2.00	1.00	1.35	-	2.75	7.10

Colour as in male except that a yellowish area is behind the median dark pattern on the abdomen. There is some variation in the colour pattern in both sexes.

Carapace and chelicerae as in male except the paired spines in front of the chelicerae are more strongly developed in female.

Maxillae, labium and sternum as in male. The legs are somewhat shorter.

Spines: *First leg*. Femur dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2. Tarsus 0. *Second leg*. Femur dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2. Tarsus 0. *Third leg*. Femur dorsal 1-1-1, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1, ventral 2-2-2. Metatarsus dorsal 0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2. Tarsus 0. *Fourth leg*. Femur dorsal 1-1-1, prolateral 1-1-1, retrolateral 1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 0. Metatarsus dorsal 0, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-2-2. Tarsus 0.

Palpi about half the length of body. Spines disposed as follows:- Femur dorsal 1-1-1, elsewhere 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1, ventral 0. Tarsus dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-2. Tarsal claw only slightly bent and with three teeth.

Abdomen long oval, furnished with short hair. Epigynum wider than long in ratio 10:9, well covered with hair; its form as fig.18. Spermathecae as seen in transparent preparations round. Six spinnerets, colulus and tracheal spiracle present.

Localities:- Tasmania Fern Tree 1 ♂ (holotype) 24.1.1960, 3 ♀♀ (paratypes) 4.11.1959. National Park 1 ♀ 29.8.1951, J.L. Hickman. Lenah Valley 1 ♂, 4 ♀♀ 1.6.1948, V.V. Hickman.

Remarks:- *Cycloctenus cryptophilus* is usually found under decaying logs in rain-forests. Males occur from Jan. to June. Females lay their eggs in early Spring. The egg-sac is lenticular and made of white silk. The female covers it with particles of rotten wood and other debris. It is attached to the underside of logs in damp sites.

Cycloctenus infrequens n. sp.

Male

Measurements in mm:-

Body length	5.55
Carapace length	2.70
Carapace width	2.05
Abdomen length	2.70
Abdomen width	1.50

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	3.25	1.10	3.25	3.50	1.60	12.70
2	3.15	1.00	3.00	3.25	1.50	12.70
3	2.65	0.95	2.50	3.25	1.70	11.05
4	3.50	1.00	3.00	3.95	2.00	13.45
Palp	1.90	0.55	0.85	-	1.10	4.40

Colour of carapace yellowish brown with radial dark markings. Palpi and legs yellowish with dark brown spots and blotches. Maxillae and labium brown. Sternum yellowish brown with darker margin. Abdomen dark brown above with an elongate yellow median area on front half with five pairs of dark spots (fig.19). Ventral surface light brown; spinnerets yellow.

Carapace oval, narrowed in front to about half its maximum width; depressed between head region and fovea. Cervical groove well marked. Fovea longitudinal and deep. Eight eyes in three rows, the first row being formed by AME, the second by ALE and PME, and the third by the large PLE. The length ratio of the three rows 3:10:12. Ratio of eyes AME: ALE:PME:PLE = 6:8:16:25. Median ocular quadrangle longer than its posterior width in ratio 35:26 and wider behind than in front in ratio 13:8. Height of clypeus about three times diameter of AME.

Chelicerae conical with lateral condyles; furrow oblique with two teeth on each margin; fang well curved; four spines on front of each paturon (fig.20).

Maxillae longer than wide in ratio 3:2; lightly clothed with hair and furnished with scopula and serrula.

Labium as wide as long; about half length of maxillae; slightly emarginate in front and fringed with long hairs.

Sternum little longer than wide in ratio 14:13, truncate in front and ending in a point between hind coxae, clothed with a few hairs.

Legs in length order 4.1.2.3, the first and second legs being equal in length. Trichobothria on tibiae, metatarsi and tarsi. Three tarsal claws; upper claws with three teeth, lower claw with one. Claw tufts absent. Trochanters not notched.

Spines:- *First leg*. Femur dorsal 0-1-1, prolateral 1-1, retrolateral 1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1, retrolateral 1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Tarsus 0. *Second leg*. Femur dorsal 1-1-1, prolateral 0-1-1, retrolateral 1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 0-1-1, retrolateral 1-1-1, ventral 2-2-2-2-2. Metatarsus dorsal 0, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-2-2-2-2. Tarsus 0. *Third leg*. Femur dorsal 1-1-1, prolateral 1-1, retrolateral 1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 1-2 apical. Metatarsus dorsal 0, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-2-2-2. Tarsus 0. *Fourth leg*. Femur dorsal 1-1-1, prolateral 1-1, retrolateral 1-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1-1, retrolateral 0-1-1, ventral 2 apical. Metatarsus dorsal 0, prolateral 1-1-1-1, retrolateral 1-1-1-1, ventral 2-2-2-2. Tarsus 0.

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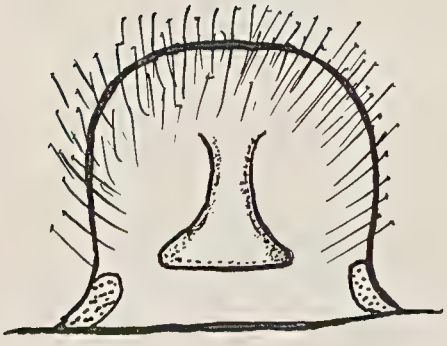

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FIGS 19-22.- *Cycloctenus infrequens* n. sp. Male: 19-body, 20-chelicera, prolateral side, 21-palp. Female: 22-epigynum.

Palp (fig.21). Spines as follows:- Femur dorsal 1-1, elsewhere 0. Patella the same. Tibia dorsal 1, prolateral 1, elsewhere 0. Tarsus with a few coarse bristles on dorsal side in basal half and apex. Tibia much longer than patella than usual and with a broad apophysis at the apex of dorsal side. The apophysis is concave below and has two prongs. The prolateral prong is long with a sharp curved point, the retrolateral prong is flat, pointed, short and with a rugose edge. Tarsus spoon-shape; the genital bulb as in figure.

Abdomen oval, about as long as carapace. Spinnerets six, front pair largest. Integument clothed with fine hairs and erect bristles. Small colulus present.

Female

Measurements in mm:-

Body length	6.55
Carapace length	3.00
Carapace width	2.30
Abdomen length	3.50
Abdomen width	2.50

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	2.75	1.00	2.50	2.15	1.25	9.65
2	2.50	1.00	2.25	2.20	1.25	9.20
3	2.50	0.75	2.00	2.50	1.50	9.25
4	3.00	0.85	2.25	3.25	1.75	11.10
Palp	1.50	0.65	0.75	-	1.00	3.90

The female resembles the male but has a larger body and shorter legs. Its colouration is similar but the yellow area on the dorsal side of the abdomen is smaller and on the ventral side of the abdomen the female has a pair of longitudinal yellow stripes.

The ratio of the eyes AME:ALE:PME:PLE = 7:9:15:20 and the median ocular quadrangle is shorter than its posterior width in ratio 32:45 and longer behind than in front in ratio 45:23.

Palp has spines as follows:- Femur dorsal 0-1-1, elsewhere 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 0. Tarsus dorsal 1, prolateral 1-1-1, retrolateral 1-1-1, ventral 2-2-2. Claw very slightly curved and with three teeth. Basal prolateral spine on tibia as long as the segment.

Epigynum wider than long in ratio 6:5, clothed with hairs. Septum is in the form of an inverted T (fig. 22).

Locality:- Tasmania, Tarraleah 1 ♂ (holotype) 7.10.1957; 1 ♀ (paratype) May 1952, V.V. Hickman.

Family AMAUROBIIDAE

This family was established by Thorell (1870) and for many years has included only cribellate forms. Since Lehtinen (1967) published his comprehensive study of the classification of cribellate spiders the cribellate condition can no longer be regarded as diagnostic of the family and many non-cribellate spiders must be included in it. Forster and Wilton (1973) considered that the family should be limited to those genera, which have a simple tracheal system and a sclerotized plate-like median apophysis. In New Zealand most members of this group are ecribellate and include seven genera, among which is the genus *Otira*. This genus contains forms having the sensory organ known as a tarsal rod. The finding of a Tasmanian species with such an organ appears worth recording.

Genus *Otira* Forster and Wilton, 1973

Otira affinis n. sp.

Male

Measurements in mm:-

Body length	2.50
Length of carapace	1.32
Width of carapace	0.97
Length of abdomen	1.12
Width of abdomen	0.77

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0.96	0.41	0.97	0.70	0.55	3.59
2	0.86	0.41	0.71	0.52	0.48	2.98
3	0.75	0.30	0.58	0.79	0.47	2.89
4	1.27	0.41	1.10	1.23	0.69	4.70
Palp	0.48	0.21	0.08	-	0.49	1.26

Carapace light brown with dark lateral margins. Black radial markings on thorax and a dark medial line from AME to thoracic fovea. Chelicerae, maxillae, labium, sternum and legs light brown. Brown bands on tibiae and metatarsi. Abdomen greyish brown with a dorsal median row of five pairs of cream spots, the hind pair being joined together. Sides and ventral surface of abdomen pale brown.

Shape of carapace oval, widest between second coxae, narrowed in front to about half maximum width. Fovea longitudinal. Ocular area longer than wide in ratio 6:5. Eight eyes in two strongly procurved rows, the hind row longer than front row in ratio 25:13. Ratio of eyes AME:ALE:PME:PLE = 1:4:6:6. The procurvature of hind row is so great that PLE are almost in front of PME. Pigmentation of rims surrounding eyes is so extensive that the ocular area is mainly black (fig.23)

Chelicerae slightly geniculate, with lateral condyles. Clothed in front with a few long setae. Furrow oblique, promargin with six teeth, the distal four shorter than the others, retromargin with two teeth. Promarginal scopula of ten barbed setae. Fang well curved (fig.24).

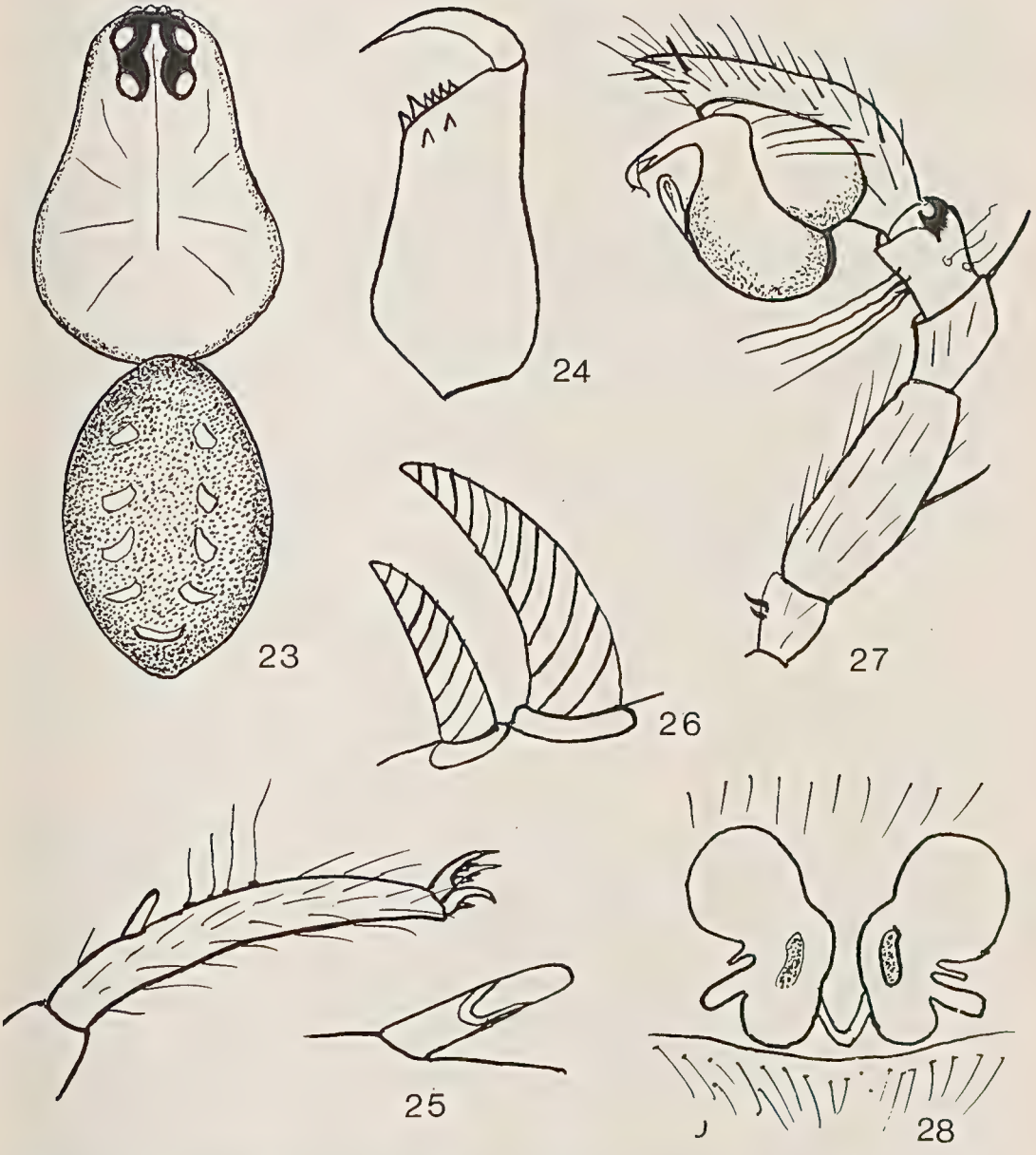
Maxillae slightly converging with a dense scopula on inner side of apical half. Apex with a serrula of about 24 teeth. Outer margin slightly curved.

Labium less than half the length of maxillae; wider than long in ratio 4:3. Front margin slightly excavated, almost straight.

Sternum shield-shape, straight in front, bluntly pointed between hind coxae. Lightly clothed with barbed hairs that slope inwards.

Legs in order of length 4.1.2.3; lightly clothed with barbed hairs. Trochanters not notched. Four trichobothria on tibia, metatarsus and tarsus. Sensory rod on all tarsi basal to trichobothria (fig.25). Upper tarsal claws of first and second legs with 7 teeth those of third and fourth legs with 4 teeth; lower claw of all legs with one tooth.

Spines are as follows but show some variation in the specimens and also on left and right sides of the one specimen. *First leg.* Femur dorsal 1-1-1, prolateral 0, retrolateral 0, ventral 0. Patella dorsal 1 apical, elsewhere 0. Tibia dorsal 1 basal, prolateral 1-1, retrolateral 0, ventral 2-2. Metatarsus dorsal 0, prolateral 1 apical, retrolateral 0, ventral 2-2-2. *Second leg.* Femur dorsal 1-1-1, prolateral 0, retrolateral 1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 0, prolateral 1-1, retrolateral 1-1, ventral 2-2. Metatarsus dorsal 0, prolateral 1-2, retrolateral 0, ventral 2-2-2. Tarsus 0. *Third leg.* Femur dorsal 1-1-1, prolateral 1 apical,



FIGS 23-28.- *Otira affinis* n. sp. Male: 23-body, 24-retrolateral side of chelicera, 25-tarsus of leg and sensory rod, 26-paired spines on trochanter of palp, 27-palp. Female: 28-epigynum.

retrolateral 1 apical, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 0-1, prolateral 1-1, retrolateral 1-1, ventral 0-1. Metatarsus dorsal 1-0, prolateral 1-1, retrolateral 1-1-1, ventral 2-2-2. Tarsus 0. *Fourth leg*. Femur dorsal 1-1-1, prolateral 1 apical, retrolateral 1 apical, ventral 0. Patella dorsal 0-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-2. Metatarsus dorsal 2-2-2, prolateral 1-1, retrolateral 1-1-1, ventral 2-2-2. Tarsus 0.

Palp has a pair of short spines on ventral side of trochanter, one 60 µm long and 18 µm in maximum width, the other 45 µm long and 12 µm in greatest width. Each is marked with oblique curved ridges (fig.26). The femur has 1-1 dorsal spines and patella 0-1. Tibia has a group of long bristles on ventral side, and four trichobothria and apophyses on dorsal side (fig.27). The tarsus is spoon-shape, clothed with hairs, and with a few short spines at apex. Genital bulb has a slender terminal apophysis and a narrow elongate conductor, which ends in a small hood-like cover for the short embolus (fig.27).

Abdomen oval, integument thin and with barbed hairs. Spinnerets small; anterior pair largest; middle pair fused into one structure with three setae at apex and two spigots on each side; hind pair minute with one spigot. Colulus present and furnished with a few hairs.

Female

Measurements in mm:-

Body length	2.51
Carapace length	1.31
Carapace width	0.97
Abdomen length	1.25
Abdomen width	0.80

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	1.03	0.45	0.89	0.68	0.48	3.53
2	0.90	0.42	0.68	0.68	0.48	3.16
3	0.82	0.40	0.55	0.78	0.48	3.03
4	1.16	0.41	0.92	1.13	0.66	4.28
Palp	0.46	0.25	0.25	-	0.48	1.44

Female resembles male in colour and markings and in most features.

Spines show some differences in number and distribution. *First leg*. Femur dorsal 1-1, prolateral 0-1. Patella dorsal 1-1. Tibia dorsal 0, prolateral 0, retrolateral 0, ventral 2-1p-2-2. Metatarsus dorsal 0, prolateral 1-1, retrolateral 0, ventral 2-2-2. Tarsus 0. *Second leg*. Femur dorsal 1-1, prolateral o-1, retrolateral 0, ventral 0. Tarsus 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 0, prolateral 1-1-1, retrolateral 0, ventral 1-1-0. Metatarsus dorsal 0, prolateral 1-1, retrolateral 0, ventral 2-2-2. Tarsus 0. *Third leg*. Femur dorsal 0-1, prolateral 0-1, retrolateral 0, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 0-1, prolateral 1-1, retrolateral 1-1, ventral 1p-1p-2. Metatarsus dorsal 0-1-0. prolateral 1-1-1, retrolateral 1-1, ventral 2-2-1. Tarsus 0. *Fourth leg*. Femur dorsal 0-1, prolateral 0-1, retrolateral 0-1, ventral 0. Patella dorsal 1-1, elsewhere 0. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 1p-1p-2. Metatarsus dorsal 2-2-2, prolateral 1-1, retrolateral 1-1, ventral 2-2-1. Tarsus 0.

Palp nearly as long as carapace; clothed with barbed hairs. Spines as follows:- Femur dorsal 0-1-1, elsewhere 0. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1, elsewhere 0. Tarsus dorsal 1-1, prolateral 1-1-1, retrolateral 1-1-1, ventral 1-1. Four trichobothria on tibia and three on tarsus. Claw with three teeth.

Form of epigynum as seen in transparent preparations is shown in fig.28. Spinnerets small; anterior pair two-segmented and with about six spigots. Middle pair 60 µm long, fused together to form a single domeshape structure with three setae at the apex and two

spigots at each side. Hind spinnerets about 57 µm long, conical, with one spigot and a long seta. Colulus and a small tracheal spiracle present.

Type locality:- Strathgordon 1 ♂ (holotype), 1 ♀ (paratype), 2 ♀♀ (paratypes) 16.5.1978 (J.L. Hickman). Other localities in southwestern Tasmania 26 ♀♀ and 142 immature specimens, Jan-March 1976 and 1977 (C. Howard, I. Hill).

Habits:- The spider occurs in moss and litter in rain-forest areas. Specimens kept in captivity spun no webs and made no egg-sacs during four weeks in April and May. Males appear in late Autumn.

Remarks:- *Otira affinis* resembles other members of the genus in having a tarsal rod instead of the usual pedal organ or drum, a similar arrangement of the eyes, the same general form of the epigynum and the peculiar paired spines on the trochanter of the male palp. It differs in having the tarsal rod basal instead of distal to the tarsal trichobothria, and also in the form of the embolus of the genital bulb.

Family MICROPHOLCOMMATIDAE

This is a family of very small spiders about 1.0 mm in body length. They occur in moss and leaf litter of rain-forests. The family was established on the characters of two species in Lorne, Victoria and two in Tasmania (Hickman 1944). Forster (1959) transferred the species to the family Symphytognathidae, but later in revising the latter family, Forster and Platnick (1977) left the species in the Microphol commatidae where they had been placed. The distribution of the family has now been extended to New South Wales and Western Australia (Main 1974). The recorded species number five.

Genus *Microphol comma* Crosby and Bishop, 1927

Microphol comma turbans n. sp.

Male

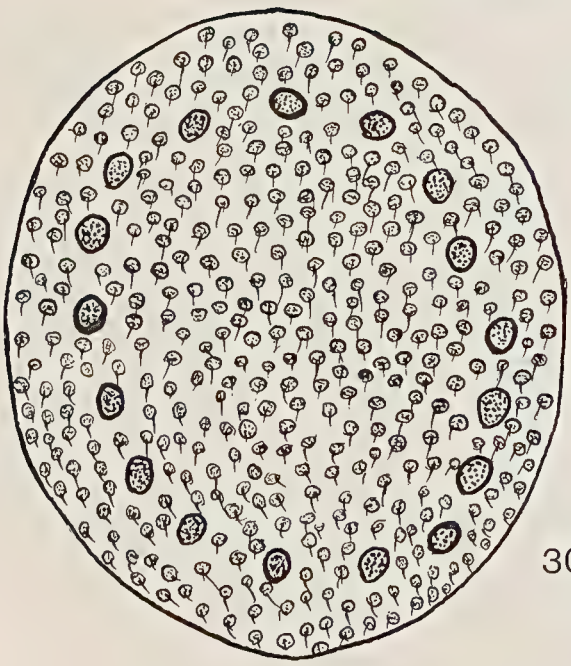
Measurements in mm:-

Body length	0.76
Carapace length	0.36
Carapace width	0.31
Abdomen length	0.59
Abdomen width	0.43

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0.30	0.11	0.23	0.12	0.22	0.98
2	0.27	0.11	0.20	0.11	0.23	0.92
3	0.25	0.09	0.18	0.11	0.20	0.83
4	0.30	0.11	0.26	0.12	0.22	1.01
Palp	0.05	0.07	0.05	-	0.09	0.26

Carapace brown with dark markings on each side; chelicerae, palpi and legs light brown; sternum with a dark spot opposite base of each coxa. Abdominal scute and sclerites brown, soft parts greyish.

Shape of carapace pyriform, head region high sloping slightly downward to the front from the thorax, which slopes steeply to hind margin. Surface smooth and polished; a few hairs scattered on the surface. Eight eyes in two rows, which occupy the width of the front of the head region. Seen from above front row slightly procurved and hind row almost straight. Eye ratio AME:ALE:PME:PLE = 10:18:15:17. AME dark, other eyes pearly white. All eyes surrounded with dark rims. Lateral eyes contiguous. ALE almost touching AME. Hind row longer than front row, and the eyes evenly spaced. Clypeus high and provided with a few hairs.



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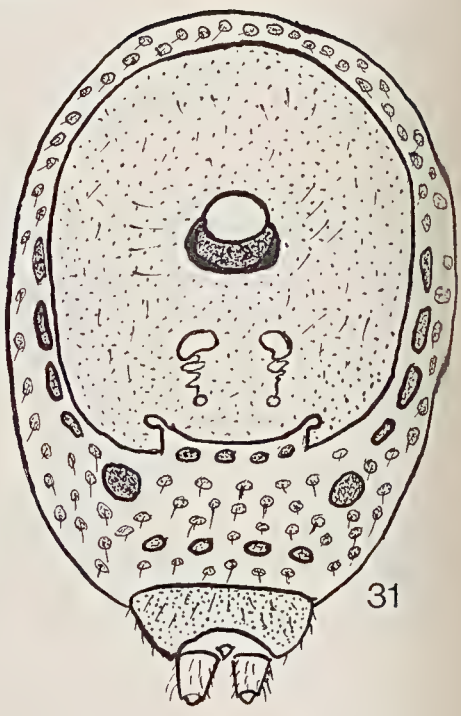

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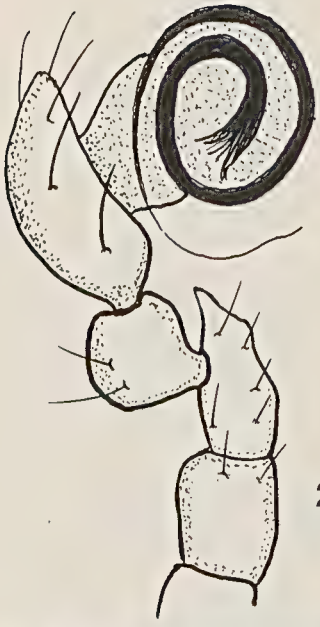

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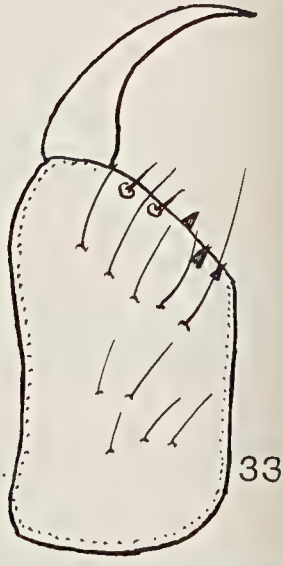

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FIGS 29-33.- *Micropholcomma turbans* n. sp. Male: 29-palp. Female: 30-dorsal side of abdomen, 31-ventral side of abdomen, 32-maxilla and palp, 33-prolateral side of chelicera.

Chelicerae 0.16 mm long, sloping slightly towards maxillae, lateral condyles and stridulating ridges absent, furrow oblique, promargin with two teeth and a spine, retromargin with one small tooth. Maxillae strongly converging, with small apical scopula and serrula. Labium wider than long in ratio 27:8, rounded in front. Sternum convex, shield-shape, rebordered, excavated round base of each coxa, truncate posteriorly and widely separating hind coxae; surface with a few hairs.

Legs in order of length 4.1.2.3. Lightly clothed with hair. One trichobothrium on the tibia of the first, second and third legs and two on the fourth. Tarsi straight with a sensory drum on dorsal side near base. Three claws, upper pair with two teeth, lower claw with none.

Palp (fig.29) with distal extension of patella to form a blunt point beyond junction with tibia. Embolus makes a coil of two turns on genital bulb. Tarsus spoon-shape clothed with hairs and a few bristles on dorsal side.

Abdomen almost covered by a dorsal scute. Sides with two folds. Ventral surface with a large epigastric scute, which is extended round the petiolus. Soft part of integument with numerous small sclerites, each carrying a hair. Spinnerets six, front pair largest. A small colulus present, which together with the spinnerets is surrounded by a sclerotized ring.

Female

Measurements in mm:-

Body length	0.84
Carapace length	0.39
Carapace width	0.32
Abdomen length	0.66
Abdomen width	0.48

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	0.27	0.11	0.20	0.12	0.23	0.93
2	0.26	0.11	0.19	0.11	0.23	0.90
3	0.22	0.10	0.16	0.11	0.21	0.80
4	0.30	0.10	0.25	0.12	0.23	1.00

The female has the same colour as the male and resembles the male in most characteristics, but is slightly larger and differs in the following features:-

Chelicerae (fig.33) have a slightly different dentition.

The palp is rudimentary consisting of a small stump projecting from the front of the maxilla at the base and showing no indication of segmentation.

The abdomen has no dorsal scute but the integument of the dorsal surface is provided with numerous small sclerites each with a short seta and the margin has a ring of larger sclerites (fig.30). The ventral surface has a large epigastric scute as in the male and the spinnerets and colulus are also surrounded by a similar sclerotized ring. On the hind margin of the epigastric scute are two small notches, one on each side, in which open the tracheal spiracles. The afferent ducts leading to the spermathecae open on the epigastric scute and may be seen in transparent preparations (fig.31).

Locality:- Southwestern Tasmania, Gordon River valley, 145°56'E, 42°37'S, 1 ♂ (holotype), 1 ♀ (paratype) from moss 5.1.1978 (L. Hill *et al.*); 145°54'E, 42°38'S, 2 ♂♂, 2 ♀♀ (paratypes) from leaf litter 5.1.1978 (L. Hill *et al.*). Other localities in the Gordon River valley from moss and litter 18 ♂♂ and 23 ♀♀ during Jan., Feb. and March 1976/1978 (C. Howard and L. Hill).

Remarks:- *M. turbans* resembles *M. caeligenum* Crosby and Bishop, *M. parmatum* Hickman and *M. mirum* Hickman in having females with vestigial palps. It differs from them in the form of the male palp. It also differs from *M. caeligenum* and *M. parmatum* but resembles *M. mirum* in the dorsal covering of the abdomen of the female. Unlike *M. mirum* it lacks the peculiar spines around the spinnerets. The females of *M. bryophilum* (Butler) and *M. longissimum* (Butler) have palps in which tibia and tarsus are fused into one segment.

LODGEMENT OF TYPES

Holotypes mentioned herein will be lodged in The Australian Museum, Sydney. Paratypes, if available, will also be lodged in The Australian Museum and in The Tasmanian Museum and Art Gallery.

ACKNOWLEDGEMENTS

My thanks are due to Drs R.R. Forster and J.L. Hickman for providing specimens for study. I am also grateful to the staff of the University Library for searching out old literature.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 115, 1981

(ms. received 9.9.1980)

ABORIGINAL SKELETAL REMAINS FROM CAPE PORTLAND

by Peter Murray and Don Ranson
Tasmanian Museum & Art Gallery, Hobart and
National Parks & Wildlife Service, Sandy Bay Tasmania

(with three tables, two text figures and four plates)

ABSTRACT

MURRAY, Peter and RANSOM, Don, 1981 (30 ix): Aboriginal skeletal remains from Cape Portland. *Pap. Proc. R. Soc. Tasm.*, 115, 69-76 (with two figures and four plates). ISSN 0080-4703. Tasmanian Museum and Art Gallery and National Parks and Wildlife Service, Hobart, Tasmania, Australia.

An aboriginal cranium and mandible (M4903) was recovered from a deflated midden deposit within the National Parks and Wildlife Reserve on the Cape Portland Estate, Cape Portland, northeastern Tasmania. No additional skeletal material was found during follow up excavation procedures that took place about two weeks after the discovery. The skull is within the known morphological range for Tasmanian aboriginals.

INTRODUCTION

A Tasmanian Aboriginal skull (Tasmanian Museum No. M4903) was discovered in a deflated midden deposit at Cape Portland by naturalist Ralph Cooper of Legana. The skull, (complete cranium and mandible) and some fish bones were presented to the museum by Piers Allbrook and Dee Mills of Hobart, shortly after the discovery which took place in February 1980. The cranium and mandible were removed from the site after their positions were marked because the prevailing wind had shifted and had commenced refilling the deflated surface upon which the remains were found.

The Tasmanian National Parks Service was informed of the find and an expedition to recover additional remains was set for the following weekend (Feb. 29th-March 2nd).

EXCAVATION

Mr Cooper kindly met us at Cape Portland and led us to the site (fig. 1). The human remains were located in a deflated midden (sheet 8416/EQ809858) that extends for about 0.5 km in a northwesterly direction. For several hours the surface was searched for human skeletal remains. No additional skeletal material was found. A grid system of 1 metre squares was laid out over the general area from which the cranium and mandible were recovered.

This area was trowelled down to 0.05 m below the surface and an adjacent test pit was dug to a depth of 0.5 metres. The sand lying directly below the surface proved to be sterile to .5 metres, indicating that all of the midden material and human remains were derived from deflated sediments lying above the surface from which they were removed.

MIDDEN CONTENTS

The midden contains remains of both vertebrate and invertebrate food items, bone and stone artifacts and some invertebrate remains that had been blown into the area (mostly tests of the sea urchin *Holopneustes* and cuttlefish). Invertebrate food remains include warrener, abalone, scallop, mussels, several small gastropod genera and limpets. Vertebrate food remains include sea lion, fur seal, swan, duck, Bennett's wallaby, forester kangaroo, mutton bird and fish remains, including parrot fish. A bone point made from wallaby fibula was found about 14 m from the human remains (plate 1). None of the material was in its original stratigraphic context although adjacent intact middens may be

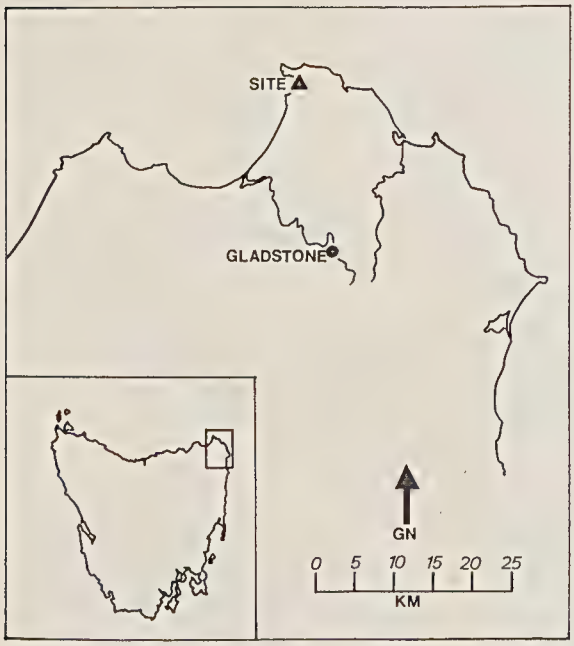

FIG.1.- Map of locality, Capt Portland, northeastern Tasmania.

contemporaneous with the deposit. These middens were also undergoing rapid erosion. They are largely confined to a thick organically stained calcarenite that is overlain by up to 15 soil horizons comprising the large dune system that dominates the area. Root casts are associated with many of these exposures.

DATING

Unless the rest of the skeleton is located *in situ* it will not be possible to assign a date to the skull. An attempt to use relative fluorine content of bone was thwarted by a lack of clear stratigraphic continuity between the various deposits.

DESCRIPTION

The specimen consists of a nearly complete cranium and mandible (plate 2). The cranium shows slight erosion of the vault due to sand blasting and rootlet invasion. Faint streaks of mineral stain are also present. There is some damage to the posterior portion of the palate and both temporal bones have irregular holes through them located just above the auditory meatus. The tips of the nasal bones are damaged and both zygomatic arches are broken. The right central and left central and lateral maxillary incisors and the right upper first molar are missing. The mandible lacks the right central incisor and the tip of the right coronoid process.

The skull probably represents a male between 20 and 30 years of age. The patent sphenoidal-basioccipital suture suggests the lower 20's. The third molars are fully erupted and well worn.

The braincase is long relative to width (cranial index = 71, dolichocephalic), with an estimated cranial capacity of 1380cc. The external occipital protuberance and associated nuchal muscle markings are only moderately well expressed. The temporal bone is broad with slight supraciliary brow ridges. Glabella is not prominent nor is nasion very deeply depressed. The parietal eminences are poorly expressed. The vault has a pentagonal outline resulting from a shallow convexity in the parietals on either side of the sagittal suture. Obelion is slightly depressed. Wormian bones are absent in the lambdoidal suture. The auditory meatus is roofed by a well developed suprameatal crest. Auditory meatal exostoses are present on both sides. The mastoid processes are eroded, but are of medium size for a Tasmanian male. The digastric groove is relatively narrow and shallow. The orbits are wide and low (orbital index = 67). The nasal bones are much abbreviated and convex. The nasal aperture is relatively long and narrow for a Tasmanian (nasal index = 54.0). The upper face is short.

The cranium displays maxillary prognathism (gnathic index = 106). The palate is relatively deep and broad. The teeth are large and attrition is marked. Interproximal wear is present on all molar crowns. Moderate to severe alveolar recession is evident. An anomalous root is present in its own alveolus buccal to the second premolar on the left side. A similar growth appears apically on the right second premolar. The right first premolar shows alveolar erosion due to an apical abscess and there is a small,

corresponding exposure on the crown.

The mandible is stout with a neutral chin and a poorly defined mental trigone. The digastric fossae are well developed and genial spines are present. The gonial angles are moderately everted. A similar degree of alveolar recession is present on the mandible.

M4903 is both metrically and morphologically within the known range for Tasmanian aboriginals and there is no reason to consider its affinity with any other racial group. It combines both minimal and maximal expressions of morphological features generally accepted as being characteristic of Tasmanian aboriginal populations.

Its features are generally delicate. The parietal eminences are only slightly expressed and there is no impression of a sagittal keel. Obelion is just perceptibly depressed. However, the external occipital protuberance is well developed, the suprameatal crest is prominent, the orbits are very low and wide and the face is short, broad and prognathous. Despite the moderate expression of many of the characteristic traits, the skull retains an overall form that is distinctly Tasmanian. This is seen in the conformation of the cranial vault, and morphology of the face and palate. The mandible is typical of Tasmanian aboriginal males.

PLATE 1.- Bone point collected from surface near skeletal remains.

This is the second skull found at Cape Portland. A previous discovery took place in March 1924 apparently under similar conditions. Occurrences of human remains are rarer on the north-east coast than on the west. Ten provenances are recorded from the entire east and north-east coast in the short distance between Mt Cameron West and Temma. Discoveries are still rarer from the south-east and south where only nine localities are recorded. It does not seem likely that material lacking provenances could account for this discrepancy. Factors such as burial/cremation practices, population size and preservational environment may be responsible.

The 1924 Cape Portland cranium (TS83) displays well developed parietal bosses, markedly convex parietals and a depression around obelion. The individual is smaller, probably a male, and is somewhat older, judging from the complete closure of the basioccipital-sphenoidal suture. There is also more attrition of the molars, and evidence of osteo-arthritis on the occipital condyles and glenoid fossae (fig. 2).

Populations in the northeast appear to exhibit about the same degree of individual variability as from from other parts of Tasmania suggesting the presence of social mechanisms leading to liberal gene flow throughout the island. Tasmanian aborigines express a comparatively high degree of morphological homogeneity, as a result of a small population size and genetic isolation.

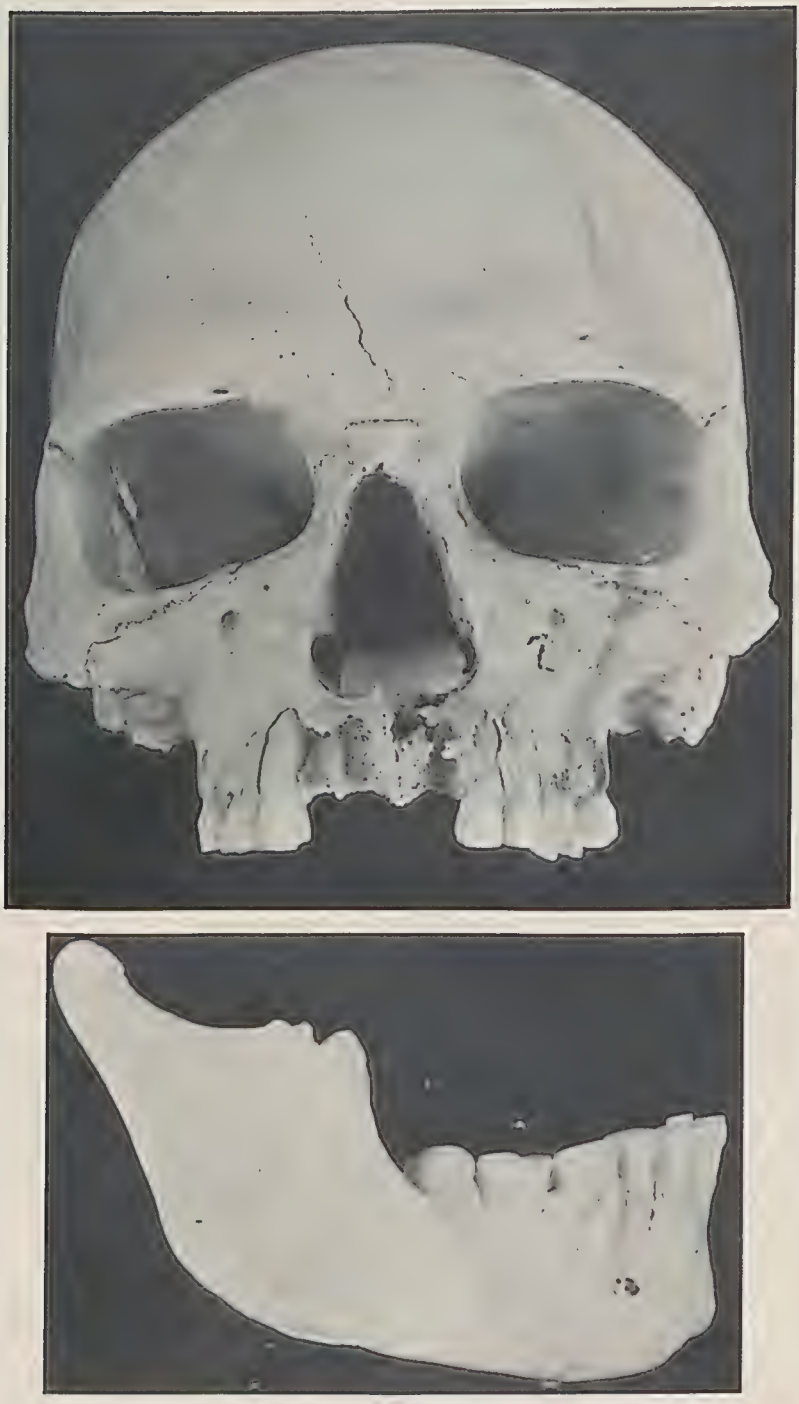

PLATE 2.- Photographs of cranium and mandible.

TABLE 1

METRIC ATTRIBUTES OF M4903

	M4903	$\bar{X}$ TASMANIAN (Wunderly'39)	(males) (Morant'27)
Maximum cranial length	183.0	185.4	182.2
Maximum breadth	129.0	138.2	136.0
Minimum frontal breadth	97.0	94.7	94.0
Basi-breg height	126.5	129.8	130.9
upper facial height	60.5	62.4	62.5
nasal height	48.0	45.1	47.1
nasal breadth	26.0	26.9	27.8
orbital height	28.0	29.3	31.1
orbital breadth	42.0	37.9	-
palatal breadth	42.0	-	-
palatal depth	15.0	-	-
maximum palatal width	65.0	-	-
maximum palatal length	62.5	-	-
minimum ascending ramus breadth	34.0	-	-
symphyseal height	25.0	-	-
minimum horizontal ramus height	24.5	-	-
Cranial Index (dolichocephalic)	71	74.2	74.2
Gnathic Index (prognathous)	106	101.4	-
Orbital Index	67	78.2	-
Nasal Index	54	59.9	59.1
Cranial Capacity - 1380cc		1247cc	1264cc

TABLE 2

CLASSIFICATION OF MOLAR WEAR (Brothwell 1972)

M^1	M^2	M^3
5	4	3

M_1	M_2	M_3
5+	5+	4

TABLE 3

MEASUREMENT OF TEETH

	Mesiodistal	Buccolingual		Mesiodistal	Buccolingual
$I_{\bar{1}}$	4.6	5.5	$I^{\underline{1}}$	-	-
$I_{\bar{2}}$	-	-	$I^{\underline{2}}$	-	-
C	-	-	C	8.0	7.5
$P_{\bar{1}}$	-	-	$P^{\underline{1}}$	7.3	10.2
$P_{\bar{2}}$	7.1	10.6	$P^{\underline{2}}$	7.3	10.0
$M_{\bar{1}}$	10.6	10.6	$M^{\underline{1}}$	10.0	12.1
$M_{\bar{2}}$	11.6	11.0	$M^{\underline{2}}$	11.0	13.0
$M_{\bar{3}}$	11.5	11.5	$M^{\underline{3}}$	9.5	11.5

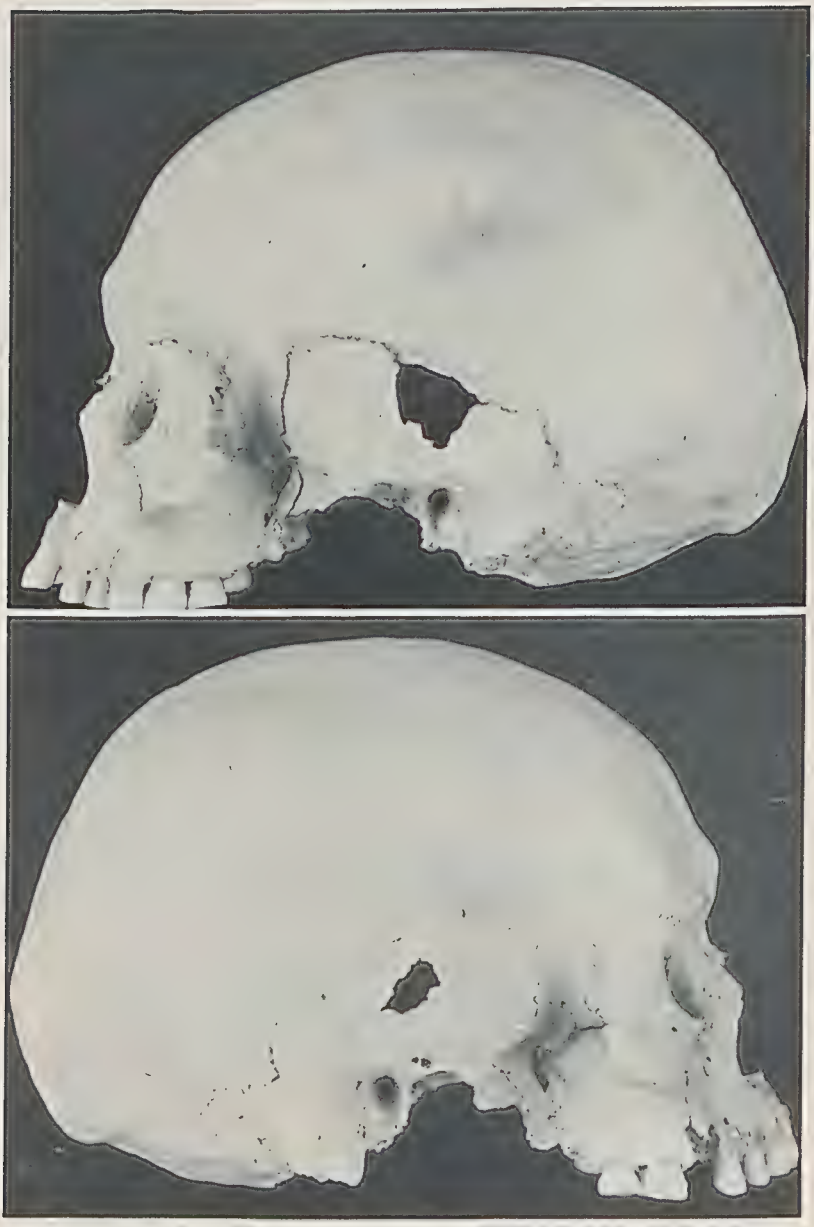

PLATE 3.- Lateral views of cranium.

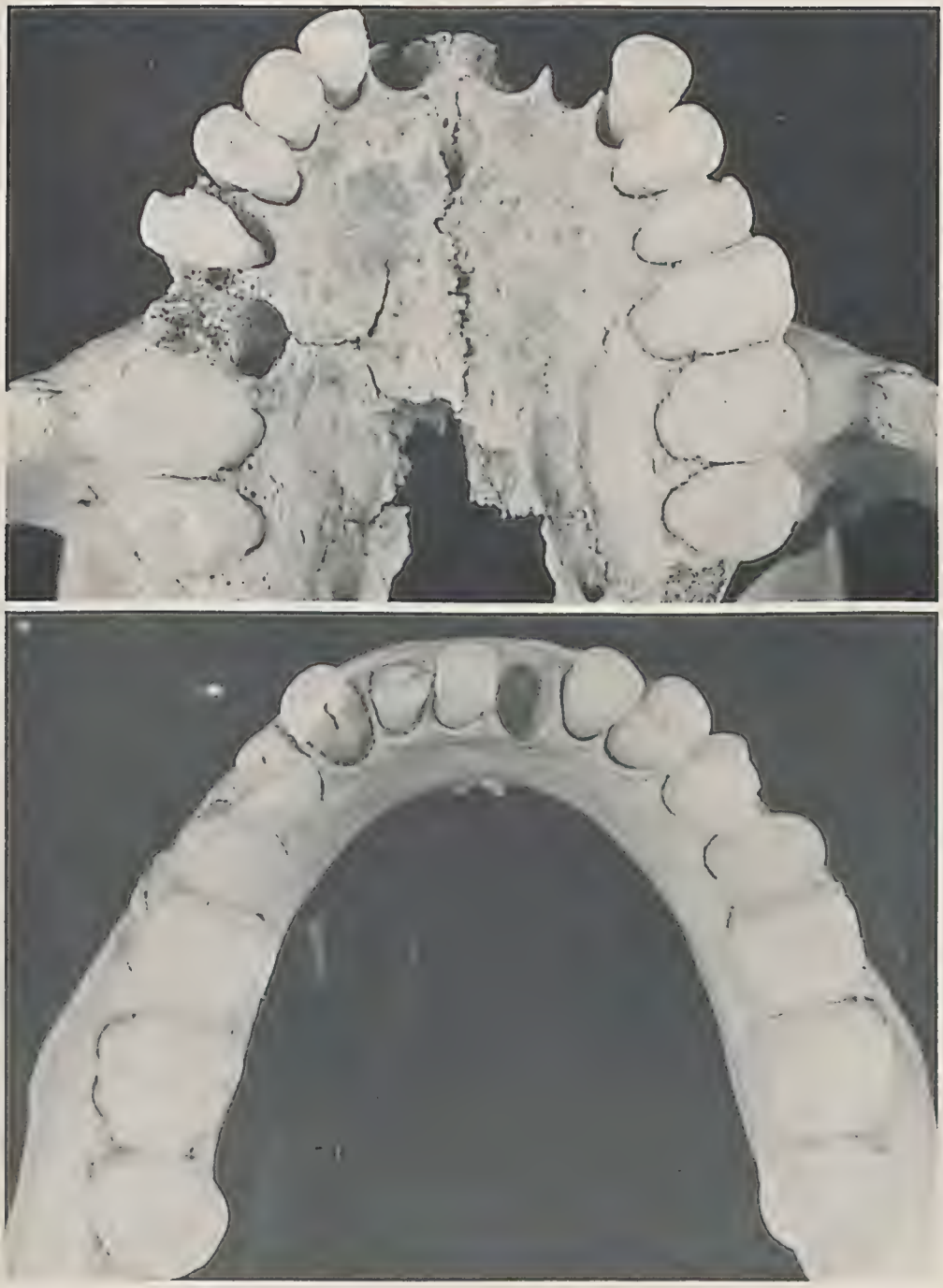

PLATE 4.- Maxillary and mandibular dentitions.

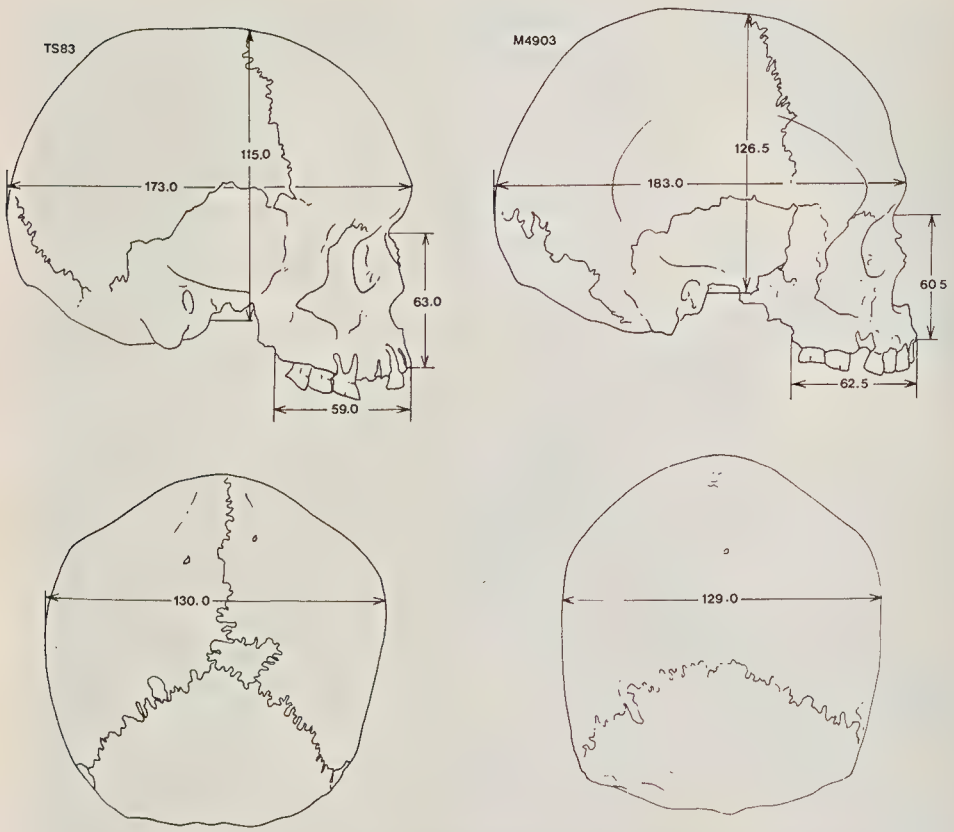

FIG. 2.- Comparison of TS83 and the new Cape Portland skull M4903.

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THE NATURAL HISTORY OBSERVATIONS AND COLLECTIONS MADE DURING FURNEAUX'S VISIT TO TASMANIA (VAN DIEMAN'S LAND) IN 1773, WITH SPECIAL REFERENCE TO BOTANY

by E. Charles Nelson
National Botanic Gardens, Glasnevin, Dublin 9, Ireland

ABSTRACT

NELSON, E. Charles, 1981 (30 ix): The natural history observations and collections made during Furneaux's visit to Tasmania (Van Diemen's Land) in 1773 with special reference to botany. *Pap. Proc. R. Soc. Tasm.*, 115, 77-84. ISSN 0080-4703. National Botanical Gardens, Glasnevin, Dublin 9, Ireland.

During the visit of H.M.S. ADVENTURE to Tasmania in March 1773 a number of animals and birds were caught or observed; several of the birds were later drawn. As well, Tobias Furneaux, captain of ADVENTURE, collected seeds of at least two plants, *Eucalyptus obliqua* and *Leptospermum lanigerum*, and herbarium specimens of the latter, which were brought back to England. The seeds were germinated and plants were growing in London gardens in the late 1770's. The possible existence of other herbarium specimens is discussed, and the reasons for the small amount of scientific collection by ADVENTURE's complement are discussed.

INTRODUCTION

A year after returning from his momentous first expedition, during which the eastern seaboard of Australia was explored, Capt. James Cook set sail again for the southern hemisphere. On 13 July 1772, H.M.S. RESOLUTION, under Cook's command, and H.M.S. ADVENTURE, under the command of Capt. Tobias Furneaux, left Plymouth for the Cape of Good Hope, which they reached on 30 October. After several weeks at the Cape, the expedition set sail again on 22 November and headed south. On 17 January 1773, the ships made the first crossing of the Antarctic Circle, but while cruising in less southerly latitudes, on 8 February, they became separated in thick fog. The instructions for the voyage laid down that if this happened, the ships would rendezvous at Queen Charlotte Sound, New Zealand (see Beaglehole 1961, 1974).

When the fog lifted, Furneaux did his best to regain his position and to make contact with RESOLUTION, but after three days he decided to bear away for New Zealand. On 9 March 1773, ADVENTURE reached Van Dieman's Land (Tasmania), making landfall about South West Cape. This was only the third time that Europeans had visited Tasmania; apart from Abel Tasman who discovered the island in 1641, a French expedition commanded by Marion de Fresne had landed at Cape Frederick Hendrick on 4 March 1772, almost one year before Furneaux's arrival.

Accounts of the visit of Furneaux's expedition have survived, including Furneaux's own log(1) and an account of ADVENTURE's voyage (2) which Furneaux wrote. The journal of the astronomer, William Bayly, the only scientist on board ADVENTURE, is also extant(3), as are the journals of Arthur Kempe (first lieutenant)(4), James Burney (second lieutenant)(5), Love Constable(6), Richard Hergest(7), Henry Lightfoot (midshipman)(8), Robert Browne(9), John Wilby (able seaman)(10) and William Hawkey (master's mate)(11). These have all been used in preparing this paper.

The short visit of ADVENTURE to Tasmania produced more zoological than botanical results; indeed it was previously considered that there were no botanical collections made in Tasmania by Furneaux or his companions. None of the people on board ADVENTURE is listed as a botanical collector in works on the history of Australian botany, including J.D. Hooker's summary of botanical exploration in Tasmania (1859). The majority of the botanical and zoological results of the second voyage resulted from the works of Johann Reinhold Forster and his son Georg who were on board RESOLUTION and who did not visit Tasmania(12).

Biological observations, Furneaux's visit to Tasmania, 1773

THE LANDING PLACES AND GENERAL OBSERVATIONS

On Tuesday 9 March 1773(13), at about 9 a.m., land was sighted from ADVENTURE for the first time since leaving the Cape of Good Hope. At 1 p.m. on the following day, Furneaux ordered the cutter to be lowered and a party was dispatched to try to make a landing. Due to deteriorating weather, the cutter was soon ordered to return to ADVENTURE. At 9 a.m. on the following day, the cutter was again launched and sent " ... onshore with the second Lieutenant to find if there was any harbour or good bay ..."(2). Burney reported that he " ... saw a Sandy Beach but could not Land there for the Surf - however we found a good Landing place on some Rocks. The first thing we Saw when we climbed up was Some Wood Ashes the remains of a Fire which had been kindled there & a great Number of Scollop Shells..."(5). Although they found these indications of an aboriginal encampment, they did not see any of the native people, and as the weather was becoming stormy the cutter soon returned to ADVENTURE. The landing at Louisa Bay east of South West Cape did not reveal a suitable anchorage for the ship.

After taking on board the cutter, Furneaux continued to sail along the coast, eastwards towards South East Cape, and then northeastwards into Storm Bay. At 4 a.m. on Friday 12 March, the cutter was again lowered to go inshore and make soundings. It returned at 8 a.m. and the crew reported that they had found a good anchoring place suitable for taking on wood and water. By 6 p.m. that evening, Furneaux had brought his ship to anchor in the bay on the eastern side of Bruny Island, which he named Adventure Bay. ADVENTURE remained at anchor there until Tuesday 16 March, when the expedition departed for New Zealand.

Furneaux wrote that the country around Adventure Bay was "...very pleasant, the soil of a rich black, tho' thin one; the sides of the hills covered with large trees..."(2). Burney's account of the same place recorded that "...The Land is situated in a fine temperate & healthy Climate - the Country is exceeding pleasant, but it is almost impossible to penetrate into it on account of the Woods..."(5).

The ship was anchored for four days, during which time the crew was engaged in "...wooding and water[in]g ye ship..."(4). As well, according to Constable "...some of the Gentlemen went on shore in the Wood Saw several wigworms [wigwams] & fier places but non of the Inhabittance nor no kind of Annimaine [animal] ..."(6). Next day, Constable was "...Employd as Yesterday...(Wooding & Water & Stowing it away)...saw no kind of Annimails but one which was shot by one of our Gentlemen Like a Poolcat [sic.] ..."(6). Burney recorded that "...We Shot some Wild Ducks, Crows, Parroquets, a White Eagle and some Small birds...we found several tracks of wild Beasts, & the dung of Some which we took to be of the Deer kind - one of our gentlemen shot at Possown...-this was the only Animal we Saw here..."(5)

Wilby provided further information; with respect to the aboriginal people he noted that "...They have nothing to Live on but Shellfish, that we can Observe, for the Birds, what Few there are is so shy, That its difficult to get a Shot at them. To the SW of the First Watering place there is a Large Lagoon which I believe has Plenty of Fish in it for one of our Gentlemen caught upwards of 2 Dozen Trout and Shot a Possom, which was the only animal we saw..."(10).

After completing the stowing of wood and water, the vessel departed, and there was no other landing made in Tasmania. ADVENTURE sailed as far north as Bass Strait, which was thought by Furneaux to be a deep bay, and then "...shaped...Course to the E'ward for New Zealand..."(6). The ship anchored in Queen Charlotte Sound, as arranged, and on 18 May 1773, RESOLUTION rejoined ADVENTURE at the Sound.

ZOOLOGICAL OBSERVATIONS AND COLLECTIONS

The zoological results of the ADVENTURE's sojourn in Tasmania are summarised by Whitley (1970).

Burney reported, after returning from landing at Louisa Bay, that he had "... brought off Several Boughs of Trees - Some Shells & Some Burnt Wood..."(5). According to Furneaux, the party that landed at this bay "...saw several places where the Indians [sic] has been and one they lately had left, where they had a fire with a great number of pearl scollop shells round it; these shells they brought onboard..."(2). Similarly, William Hawkey noted that the cutter's crew had found "...a Number of Oister & other shells laying round...some which they brought on Board..."(11).

At Adventure Bay, as the quoted portions of journals show, other animals were encountered; fish and a snake were caught, birds and animals shot (see Beaglehole 1961, Reed 1969, Whitley 1970). The fish caught in the lagoon were called "trout"; these have been identified as either *Galaxias attenuatus* or *G. truttaceus* (see Beaglehole 1961, Whitley 1970). A "possom", identified by Whitley (1970) as the Tasmanian possum (*Pseudocheirus convoluter*) was shot by one of the gentlemen; Wilbey recorded that it "...has a false belly..."(10). Burney reported "...a great Number of very large Ants [probably *Myrmecia forficata*] about an Inch & a half long - they bite very sharp & are exceeding troublesome"(5).

In Furneaux's report of the visit to Tasmania, there are mentions of other animals, some of which can be identified: "...the Land birds we saw are a bird like a Raven [*Corvus coronoides*]; some of the Crow kind, black... [probably the black currawong or bell magpie, *Strepera arguta*] some Paroquets, and several kinds of small Birds [see below]. The Sea Fowl, are Duck, Teal and Sheldrake [mountain duck, *Tadorna tadornoides*]. I forgot to mention a large white bird that one of the gentlemen shot, about the size of a large Kite of the Eagle kind [see below]. As for Beasts we saw but one which was a Possum...The Fish in the Bay are very scarce; those we caught were mostly Sharks, Dog fish [*Flakeus megalops*] and a fish...like a dog fish only full of small white spots, [*Squalus kirkii*], and some small fish not unlike spratts [*Clupea bassensis*]. The Lagoons (which were breakish [sic]) abounds with trout and several other sort of Fish, of which we caught a few with lines ..."(2).

Furneaux recorded that he named Penguin Island, south-east of Adventure Bay "... from a curious one we caught there..." The captured penguin lived for several days after being caught, but died and later the preserved skin was given to J.R. Forster by "... the celebrated Captain Tobias Furneaux..." when the two ships were reunited (Whittell 1954). Georg Forster made a pencil sketch of it which is unfinished, and is now among other drawings made during Cook's second voyage, held in the British Museum (Natural History). The identity of this penguin has presented problems; Whitley (1970) and Hindwood (in Reed 1969) identified it as *Eudyptes cristatus*, but Falla (see Lysaght 1959) considered that the drawing made by Georg Forster represents the Royal penguin (*Eudyptes chrysolophus schlegii*). J.R. Forster described the penguin in his paper on these birds *Historia Apentodytae, generis avium orbi australi propii* (1781).

The "...white bird...of the Eagle kind..." was also sketched by the younger Forster; the drawing represents the white goshawk (*Accipter novaehollandiae novaehollandiae*). The goshawk was described by Latham (1781) who said it was "...communicated by Dr G.R. Forster [sic]..." and that he had relied on Forster's description (Whittell 1954, Whitley 1970, Lysaght 1959). As with the penguin the skin of the hawk would have been given to the Forsters sometime after RESOLUTION joined ADVENTURE at Queen Charlotte Sound in May 1773.

There is a third painting of a Tasmanian bird which was done by an artist on Cook's second voyage (see Lysaght 1959). Two copies of the painting exist, depicting the tawny-crowned honey-eater (*Glyciphila melanops*); Lysaght (1959) indicates that the Tasmanian race of the species is the one shown. The artist's name is unknown, and there is no reference in the extant accounts of any honeyeater being captured or shot at Adventure Bay, although Burney said that "...some small birds..."(5) were shot. The Forsters do not appear to have seen this species - it is not among Georg's illustrations. Two further paintings of Australian birds, possibly prepared from specimens collected in

Tasmania during ADVENTURE's visit, are noted by Medway (1979); these are a green rosella (*Platycercus caledonicus*) and the black-faced cuckoo-shrike (*Coracina novaehollandiae*).

BOTANICAL OBSERVATIONS AND COLLECTIONS

The botanical results of the visit to Adventure Bay are less easily documented, as it seems that no substantial collection of plants was made, or at least, none has survived. However the report made by Furneaux, and the journals of the other members of ADVENTURE's complement clearly indicate that some plant specimens were collected.

At Louisa Bay, the landing party brought on board partly burnt fire wood as well as "...green boughs..."(2). Midshipman Hergest is more explicit in his journal, describing the specimens as "...several kinds of shrubs..."(7). The purpose of collecting the "shrubs" is not recorded, but Constable said that the "...several Green Boughs...was [sic] a pleasant Sight to us..."(6).

At Adventure Bay, various observations were made on the local tree species; these observations arose directly from the fact that the crew cut down trees for wood for the ship. The gum was also noted by Burney who described the trees as "...mostly Evergreens, standing very thick and close together - many of the Small ones bore berries of a spicy flavour - the larger ones are in general quite Strait & Shoot up very high before they branch out. They are large enough for Masts for any Ship in the Navy, but are rather brittle and heavy - they have a Soft thick bark which many of them have been stripped of by the Natives - the Wood is of a reddish cast & has a great deal of gum in it..."(5). Wilby, noting the freely flowing gum, wrote that at Adventure Bay "...there are a great many Gum Trees and of a vast Thickness and Hight one of which measured 26 feet & ye Height under the Branches was 20 feet..."(11). Furneaux noted that the large trees grew "...to a great height before they branch off; they are all of them...of a different sort to any I ever saw; the wood is very brittle and easily split, there is a very little variety of sort, having seen but two, the leaves of one is long and Narrow, the seed (of which I got a few) was in the shape of a Button, and had a very agreeable small; the Leaves of the other are like a bay and has a seed like a white thorn, with an agreeable spicy taste and smell. Out of the trees we cut down for Fire wood there issued some Gum, which the Surgeon called Gum lac..."(2). Thus Furneaux explicitly noted that he collected seeds of one of the trees at Adventure Bay and from entries in William Aiton's catalogue of plant growing in the Royal Gardens at Kew in 1789 and other records, it must be concluded that Furneaux brought these seeds back to England (see Nelson in prep.). Aiton (1789) attributed to Furneaux the introduction of *Eucalyptus obliqua* from Van Dieman's Land in 1774, and also *Leptospermum lanigerum* (syn. *Philadelphus laniger*) at the same time. Beaglehole (1961) identified the tree with long, narrow leaves and a seed "...in the shape of a Button..." as *Eucalyptus globulus*, but the vague description could also apply to *Leptospermum lanigerum*. In the herbarium of the British Museum (Natural History), London (BM) there is a sheet bearing numerous pieces of *L. lanigerum*, which has inscribed on the back "Nova Cambria. Van Dieman's Land? Capt. Furneaux 1774" - the reason for, and the meaning of the question mark are uncertain. This sheet has only fruiting twigs of the species attached, but the capsules are full of seeds; this must represent the collection he noted in his journal. As well as this native collection, there are two specimens taken from cultivated plants growing at Kew in 1778 and in Sir Joseph Banks' own garden, Spring Grove, in 1779; both of these must have been raised from Furneaux's seed, as the only other collection of Tasmanian plants and seed, made by William Anderson and David Nelson, did not reach Great Britain until October 1780 (see Nelson in prep.) The identification by Beaglehole (1961) of the tree with leaves "...like the bay [*Laurus nobilis*] and...a seed like the white thorn..." as *Eucalyptus obliqua* is acceptable. In the British Museum (Natural History) herbarium is a specimen inscribed "Hort. Comte de Coventry 1775" (the original inscription "Hort. Malcolm 1775" was altered to this). Again this must have been raised from Furneaux's seed. *E. obliqua* was named by L'Héritier (1789) who had seen seedlings during a visit to Kew in 1786 and 1787. It is possible that plants raised from Furneaux's seed were not alive when L'Héritier was in London, for he does not mention Furneaux's name. In contrast Aiton (1789) makes no mention of Nelson

or Anderson, although Nelson also collected seed of *E. obliqua* at Adventure Bay in 1777 (see Nelson in prep.) It is remarkable that the only two introductions clearly attributed to Furneaux by Aiton can be related to plants mentioned in his account of the expedition's stay at Adventure Bay. The fact that *Eucalyptus obliqua* was listed in William Malcolm's catalogue of plants for sale in 1778, two years before 1780 when Nelson's seeds reached England, is also interesting; it suggests that Furneaux collected a large quantity of seeds (Nelson in prep.)

The journals and accounts written by Furneaux and his crew only indicate that haphazard collections were made in Tasmania; there is no indication of any systematic scientific study. It is unknown what happened to the "green boughs", but the fate of Furneaux's seeds is now clear. It is also evident that some small specimens collected in the wild were preserved. Is it possible that other specimens exist?

For other material to exist, requires that someone aboard H.M.S. ADVENTURE was sufficiently motivated to retain the "green boughs", fruits, bark and even "sticks" collected, and to hand over the preserved material to the proper authorities on returning to England, although they could have given specimens to the Forsters. The fact that at least two bird corpses were preserved long enough to be seen and drawn by Georg Forster, and that seeds and specimens of *Leptospermum lanigerum* reached England, is important. There is no mention in Johann Forster's own journal of any botanical specimens being handed over by Furneaux at Queen Charlotte Sound; all that is recorded is that on 19 May "...Capt. Furneaux breakfasted with us, & we heard many curious acc^{ts} of their going to Van Dieman's Land..."(14). But, Admiralty Minutes for 24 January 1775 note that curiosities" brought back by Furneaux were to be sent to the trustees of the British Museum (Beaglehole 1961, p. 951).

As well as the *Leptospermum lanigerum* specimens in the British Museum (Natural History), there is in the Academy of Natural Sciences, Philadelphia (PH) an herbarium specimen labelled "Daphne villosa New Holland (Forster)" (see Apfelbaum 1977). This came originally from A.B. Lambert's herbarium, and Ewan(15) suggested that it came not from Forster but from the French botanist Jacques J.H. de Labillardière, and that the insertion of the name "Forster" by Pickering was incorrect. Lambert did receive material from both Labillardière's and Forster's collections. The problem which arises is whether the annotation crediting Forster with the collection is accepted or rejected. As there now is evidence that Tasmanian collections were made during Furneaux's visit, and as botanical as well as zoological specimens could have been handed over by Furneaux to the Forster, it seems illogical to dismiss Pickering's annotation. The argument that Labillardière was the collector has no substance. The specimen is identified only as *Pimelea* sp. by Alfelbaum (1977); until a firm name is established, it is not certain that it is even a Tasmanian species.

I have shown above that botanical collections were made, albeit in a cursory way, during Furneaux's visit to Tasmania in 1773. His specimens of *Leptospermum lanigerum* are the earliest extant ones of any Tasmanian plant, and mean that his name, at least, should be added to the inventory of Australian botanical collectors, even though only a few species are concerned. Furneaux also introduced into cultivation in England at least two Tasmanian plants, including the first eucalypt, which was also the first Australian plant to become commercially available to English gardeners. It is possible that observant botanists will uncover other specimens from Tasmania collected during this expedition now that attention has been drawn to their probable existence.

SCIENCE ON ADVENTURE

In conclusion, it may be worthwhile considering the scientific milieu on ADVENTURE as there does not seem to have been any attempt by Furneaux or his companions to make scientific collections, despite the fact that they knew that they were the first Europeans to land there since Tasman (at that time Marion de Fresne's landfall would not have been known to Furneaux). Although three bird species were painted and seeds of two plants were returned to England, the impression gained is that these results were almost accidental.

Biological observations, Furneaux's visit to Tasmania, 1773

Most of the natural history observations made during Cook's second voyage came from the work of Johann Forster and his son, the "official naturalists", on board RESOLUTION; the botanist/physician, Anders Sparrman, who joined RESOLUTION at Cape Town, and the assistant surgeon on that vessel, William Anderson, were also interested in the natural history of places visited. The only scientist on ADVENTURE was the astronomer William Bayly, who made observations in Tasmania, but there is no record of him undertaking botanical or zoological research. The only other member of ADVENTURE's crew competent enough to have made scientific studies was the surgeon Thomas Andrews. Watts (1979) made some interesting observations on the physicians attached to the expedition; he described RESOLUTION's team as "serious and competent...educated medical men with the care of the ship's company at heart..." They were interested also in non-medical matters Patten, for example, amassed an ethnographical collection. Watts commented that ADVENTURE "...was by no means so fortunate in her surgeons. Thomas Andrews was a boisterous, hard-drinking type...John Kent, the surgeon's first mate...had odd friends (especially James Scott, lieutenant of marines), and we know nothing about the second mate James Young...It is little wonder, that in these hands, scurvy made rapid progress in the ADVENTURE..."especially after leaving New Zealand in 1773. It is not known if the surgeon and surgeon's mates on ADVENTURE made any scientific records, as their journals are not extant.

Apart from the personalities of the "scientific" gentlemen on ADVENTURE, which appear to have influenced the crew's health and probably the amount of scientific information gathered, Furneaux was under orders to reach Queen Charlotte Sound. Clearly he decided to get there as rapidly as possible, in the expectation of rejoining Cook. Cook however felt it necessary to remain for almost seven weeks at Dusky Sound, in the South Island of New Zealand; Watts (1979) suggested that this lengthy stay happened because "...not only had [Cook] been worried about the outbreak of scurvy, but also...the crew were much longer convalescing than he had anticipated." On arrival at Dusky Sound, Cook referred to "scorbutic people" on board RESOLUTION.

The problem of scurvy is interesting, for its presence among a ship's crew should have been sufficient in itself to stimulate botanical studies. It was known at this time that fresh green vegetables could prevent and eliminate scurvy, and while on shore, ship's captains could have instructed members of the crew knowledgable about botany to search for suitable plants - in unexplored regions, like Tasmania, plants had to be treated with care, as they could prove poisonous. While the search for antiscorbutics was not the only impetus to botanical research, it should have had some effect, but in Tasmania, Furneaux seems to have been much more concerned to take on wood and water, and depart, than to allow botanical investigations which might have supplemented the diet of his crew and improved their well-being.

This lack of concern about fresh food is demonstrated by later events and clearly disturbed Cook. After leaving Queen Charlotte Sound in June 1773, the progress of scurvy on ADVENTURE was rapid; the "dirty and indolent" cook died of it, and was replaced by a cook from RESOLUTION. At the same time, late July 1773, Cook gave Furneaux precise instructions regarding the collection of local green vegetables. Cook reported to the Admiralty Secretary on his return to England (see Beaglehole 1961, Badger 1970) that "...we came to few places w[h]ere either ye art of Man or Nature had not provided some sort of refreshment or other, either in ye Animal or Vegitable way, & it was [my] first care to procure them...& Oblig'd ye people to make use of them, both by example & authority. It is from these kinds of refreshment I can only Account for the Resolution having few or no Scorbutic people on board on our passage from New Zealand to Otahiete [Tahiti] the first time, when at the same time ye Adventure had many of her best men far gorne [sic] in that disease; for except Fish they had hardly any refreshments from ye time we left ye Cape [of Good Hope] till I join'd them in Queen Charlotte's Sound, which was about Six Months; they were unacquainted with the method of making Spruce Beer & Strangers to many of ye Vegitables with which the place abounds..."(16).

This report indicates that Furneaux was complacent about instructing his crew to collect native plants, and also that he and his colleagues were not well-informed

botanically. Even though Furneaux had had gardens planted at Queen Charlotte Sound, he appears to have made little use of them. Perhaps they were not mature enough. Yet, on the arrival of RESOLUTION at the Sound "...Mr. Kemp went out to her with fish and Sallad from the Garden..."(5), and Cook later inspected "...the different Gardens Captain Furneaux and his officers had planted with garden seeds roots &ca all of which were in flourishing condition..."(17) Burney noted that "...Every thing we Set in the garden is in a fair way - nothing has faild..."(5). Certainly Cook's report to the Admiralty and his excursions to collect local native plants imply that the gardens Furneaux planted were insufficient for both crews' needs.

Furneaux placed his confidence in cider as an antiscorbutic (see e.g. Badger 1970, Beaglehole 1961, Watts 1979). Cook favoured fresh food. Beaglehole (1970) commented that although sea captains knew all about the efficacy of fresh food in preventing and curing scurvy, and tried to get fresh food when they could, "...they did not think about it enough...Tobias Furneaux, a very competent sailor, is a beautiful example..." of such a captain. Cook thought about it constantly, and would often row many miles each day in search of likely native plants; for example the day after RESOLUTION and ADVENTURE were reunited at Queen Charlotte Sound, Cook wrote in his log that "...Knowing that sellery [sic] and Scurvey grass and other vegetables were to be found in this Sound... which is [sic] extreemly beneficial in cureing and preventing Scurvey, I went my self at day light in the Morn in search of some and returned by breakfast with a boat load..."(18).

In none of the journals for the period ADVENTURE was in Tasmania is there any mention of greens being collected, apart from the enigmatic "green boughs"; no one emulated Cook! Furneaux and his colleagues were disinterested, or botanically ignorant, even though scurvy was the most serious problem they faced on long sea passages. This lack of concern as well as Furneaux's desire to reach New Zealand as quickly as possible, and his obvious reluctance to allow scientific studies - he refused Bayly a boat to make studies of tidal irregularities in Adventure Bay - all combined to limit the amount of scientific work that could be done, and the collections that could be made.

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NOTES

This paper is based mainly on documents transcribed by J.C. Beaglehole (1961), THE JOURNALS OF CAPTAIN JAMES COOK. II. THE VOYAGES OF THE RESOLUTION AND ADVENTURE 1772-1775. However Beaglehole did not transcribe fully the journals of ADVENTURE's crew; I have consulted the original journals for several of these people.

1. Log of Tobias Furneaux, captain of H.M.S. ADVENTURE, see Beaglehole, *op. cit.*, pp.149-153. (original not seen).
2. Account of ADVENTURE's voyage written by Furneaux, see Beaglehole, *op.cit.*, pp.729-736. (original not seen).
3. Journal of William Bayly, astronomer on ADVENTURE, transcribed extracts in Beaglehole, *op.cit.*, pp.149-153 (footnotes) (original not seen).
4. Log of Arthur Kempe, ms. in Public Record Office (P.R.O.), London Adm 51/4520/1-3.
5. Log of James Burney, transcribed extracts in Beaglehole, *op.cit.*, pp/746-749 (original not seen).
6. Journal of Love Constable, ms. in P.R.O., Adm 51/5420/7-8.
7. Journal of Richard Hergest, ms. in P.R.O., Adm 51/4522/13.
8. Log of Henry Lightfoot, ms. in P.R.O. Adm 51/4523/5.
9. Journal of Robert Browne, ms. in P.R.O. Adm 51/4521/9-10.
10. Journal of John Wilby, ms. in P.R.O., Adm 51/4522/14.
11. Log of William Hawkey, ms. in P.R.O., Adm 55/4521/11

12. In a previous paper (*Pap. Proc. R. Soc. Tasm.*, 108 (1974) : 160) I stated incorrectly that the Forsters had collected in Tasmania.
13. The dates and times are those used in journals and logs; dates have not been altered to allow for the difference between the civil and nautical day (the latter begins at noon).
14. Journal of Johann R. Forster, ms. in Staatsbibliothek Preussischer Kulturbesitz, Berlin (ms germ quart 222-227) entry for 19 May 1773.
15. annotation on specimen in PH, see Apfelbaum (1977).
16. Letter from James Cook to Admiralty Secretary, see Beaglehole, *op.cit.*, pp.954-955 (original not seen).
17. Journal of James Cook, see Beaglehole, *op.cit.*, pp.166-167.
18. ibid., p.165.

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PALAEOMAGNETIC RESULTS FROM THE GORDON SUBGROUP OF TASMANIA: FURTHER EVIDENCE FOR A LATE CRETACEOUS MAGNETIC OVERPRINT IN SOUTHEASTERN AUSTRALIA

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(with one table and four text-figures)

ABSTRACT

SHARPLES, Chris and KLOOTWIJK, Chris T., 1981 (30 ix): Palaeomagnetic results from the Gordon Subgroup of Tasmania: further evidence for a Late Cretaceous magnetic overprint in southeastern Australia. *Pap. Proc. R. Soc. Tasm.*, 115, 85-91 (with four figures). ISSN 0080-4703. University of Tasmania and Département des Sciences de la Terre, Université, Paris 7, Paris, France.

A thermal demagnetization study of 48 limestone samples from the Ordovician Gordon Subgroup of Ida Bay (Tasmania), indicated complete remagnetization (D = 9.4°, I = -81.4°, k = 137.5, α95 = 1.3°, N = 92 South pole position 59.8°S 141.1°E, dp = 2.4°, dm = 2.5°) during Late Cretaceous or less likely Early Tertiary time. This finding further supports a recently recognized Late Cretaceous remagnetization event in southeastern Australia, which is attributed to rift forming processes preceding the opening of the Tasman Sea. Conodont colour indicates that the limestones studied have not been subjected to temperatures in excess of 100°C. This suggests a possible widespread occurrence of this magnetic overprint.

INTRODUCTION

Little palaeomagnetic work has been done on Palaeozoic rocks in Tasmania. The only published palaeomagnetic study of the Tasmanian Ordovician is by Briden (1967), who found that the natural remanent magnetization (NRM) of certain Lower Ordovician sandstones represented a secondary magnetization. Briden regarded this as resulting from regional heating during the Tertiary.

The limestones in the Ida Bay region of southern Tasmania are amongst the least folded and the least altered Ordovician rocks in Tasmania. It was hoped, therefore, that they would retain a primary magnetization, thus allowing the determination of the palaeolatitude of Tasmania at the time of limestone deposition.

This study was initially undertaken by one of the authors (C.S.) as part of a broader sedimentological study of Ordovician rocks in the Ida Bay area. The laboratory work in this project was undertaken at the palaeomagnetic laboratory of the Australian National University in Canberra.

GEOLOGICAL SETTING

The limestones studied here belong to the Ordovician Gordon Subgroup (Corbett and Banks 1974) and outcrop on Marble Hill (146° 51'E. 43°28'S) near the township of Ida Bay in southern Tasmania (fig. 1). A stratigraphic thickness of over 350 metres of tidal flat limestone deposits (mainly intertidal and supratidal micrites) is represented and is of probable uppermost Chazyan to Trentonian age (Sharples 1979). The limestones are underlain by sparsely fossiliferous Lower Ordovician quartzites.

The Ordovician sediments are folded into a gentle meridional anticline which probably results from the Devonian Tabberabberan Orogeny. Maximum dips of only 13 degrees have

Palaeomagnetic Results from the Gordon Subgroup of Tasmania

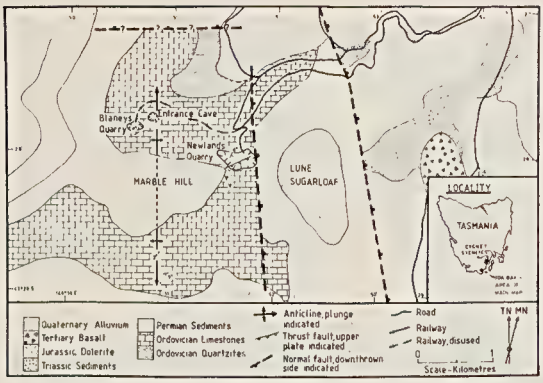

FIG. 1.- Geological sketch map of the sampling area after Sharples (1979).

been measured in the limestones on Marble Hill, and the limestones are warped into a slightly domal structure with northward and southward dip components on the north and south sides of the hill, respectively. Petrographically, the limestones show no signs of metamorphic alteration, although diagenesis has resulted in dolomitisation, dedolomitisation and calcite-pseudomorphing of evaporite crystals.

Dissolution of limestones in acetic acid for retrieval of conodonts revealed the presence of microscopic crystals of pyrite and other metallic minerals (probably including magnetite and haematite). On the grounds of their well-formed unabraded faces, these crystals are regarded as being of authigenic origin.

At the top of Marble Hill the limestones are unconformably overlain by flat-lying Permo-Carboniferous tillites, arenites and lutites. A sill of Jurassic dolerite over 100 metres thick intrudes Permian sediments in the hills east and west of Marble Hill; it must originally have been present at not less than 120 metres vertically above the uppermost limestone beds. Another large Jurassic doleritic body intrudes Triassic sediments over 1.5 km east of the easternmost limestone outcrop sampled for palaeomagnetic purposes.

A basalt flow of limited extent and probably of Tertiary age, outcrops 3 km east of Marble Hill. The only igneous rocks of Cretaceous age in southern Tasmania are the syenites in the Cygnet area, 30 km northeast of Ida Bay, which have been radiometrically dated at 99 m.y. (McDougall and Leggo 1965).

METHODS EMPLOYED

Block samples were collected from two quarries about 1.5 km apart on the northern side of Marble Hill (fig. 1, Table 1). At Newland's Quarry 36 samples were collected over a stratigraphic interval of 135 metres, and at Blaney's Quarry 12 samples were collected over a stratigraphic interval of 11 metres. Generally three samples were taken over 1 to 2 metres laterally within a bed of up to 1 metre thickness. All samples were oriented in the field with a Brunton compass. The specimens were collected from fresh faces, and show no evidence of alteration by weathering. Between one and four oriented cores (25 mm diameter) were drilled in the laboratory from each sample, and were sliced into specimens 22 mm long.

The specimens were subjected to progressive thermal demagnetization to 520°C, using furnaces as described by McElhinny *et al.* (1971). By this stage intensities were very low and probably in the noise level. All remanent magnetization measurements were made on a two-axis superconducting rock magnetometer (ScT, noise level less than 2.10^{-2} mAm^{-1}), which was interfaced for online data reduction with a Hewlett Packard 2116B minicomputer.

The magnetic content of each specimen was analyzed from Zijderveld plots (1967, 1975) and directions of individual components were determined using a principal component analysis program adapted from Kirschvink (in press).

TABLE 1

SUMMARY OF PALAEOMAGNETIC DIRECTIONS AND POLE POSITIONS
GORDON SUBGROUP LIMESTONES IDA BAY TASMANIA (146°51'E 43°28'S)

	INITIAL NRM DATA		MEAN SPECIMEN DIRECTION[1]					S. POLE POSITION		
	N[2]	Intensity[3]	Decl. (°)	Incl. (°)	k	α95 (°)	N[4]	Lat. (°S)	Long. (°E)	dp (°)
BIB13-24	12(49)	3.5-24.9	16.3	-79.9	256.5	1.9	24	61.7	135.1	3.7
BIB03-12 and BIB65-79	36(123)	1.3-23.3	6.9	-81.9	120.5	1.6	68	59.0	142.8	3.0
Combined	48(172)		9.4	-81.4	137.5	1.3	92	59.8	141.1	2.4

BEDDING CORRECTED DIRECTION

	dm (°)	Decl. (°)	Incl. (°)	k	α95 (°)
BIB13-24	3.6	66.3	-79.5	142.0	2.5
BIB03-12 and BIB65-79	3.1	330.3	-80.8	101.0	1.7
Combined	2.5	353.3	-82.9	64.7	1.9

[1] Unit weight given to individual specimen directions.
[2] Number of samples, number of specimens studied for NRM directions is given between brackets.
[3] Intensity is given in mAm^{-1}.
[4] Number of specimens demagnetized and used in the calculation of the mean characteristic direction.

RESULTS

The specimens studied showed the consistent and very dominant presence of a characteristic magnetic component with a blocking temperature range of 150°C to 450°C (fig. 2). Some samples showed additional presence of a recent local field component which was generally removed at 150°C to 200°C. This recent field component, if recognizable at all, was of low magnetic intensity. Consequently the mean grouping of the characteristic directions (fig. 3B) and of the NRM directions (fig. 3A) are rather similar. The mean characteristic direction for the individual sites (table 1) are statistically indistinguishable from each other but this is no longer so after application of a correction for bedding. The characteristic magnetization is therefore considered to postdate the Devonian Tabberabberan folding phase.

INTERPRETATION

The palaeomagnetic pole position corresponding with the characteristic magnetization component determined in this study (table 1) falls close to the Late Cretaceous and also to the Early Tertiary parts of the Australian apparent polar wander path (APWP, fig. 4), as revised by Klootwijk and Peirce (1979), but is nowhere near to the Ordovician segment of the Australian APWP (Goleby in press). Consequently, we interpret this characteristic component as representing a magnetic overprint of most probably Late Cretaceous age. This remagnetization cannot be accounted for by heating effects of the Jurassic doleritic sill as is clear from comparison of the present results with the revised APWP for Australia, neither can it be attributed because of its distance to direct heating effects of the Tertiary (?) basalt flow.

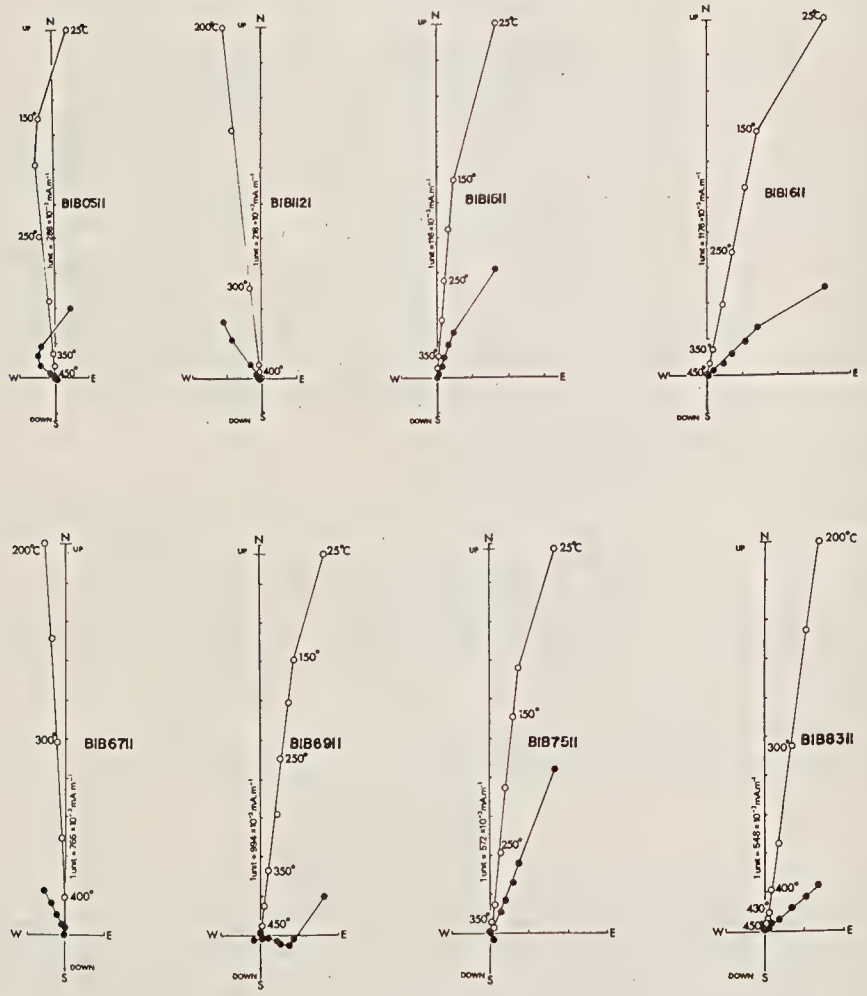

FIG. 2.- Demagnetization diagrams of representative specimens. The points denote successive positions - in orthogonal projection - of the end points of the resultant magnetization vector during progressive thermal demagnetization. Open circles denote projections on the vertical east-west plane, dots denote projections on the horizontal plane. Numbers denote successive peak temperature values. All plots are shown without correction for bedding.

It is possible but unlikely that this overprinting may have resulted solely from regional heating associated with the Late Cretaceous intrusion of the Cygnet Syenite complex, which outcrops in the Port Cygnet region 30 km northeast of Ida Bay. Country rocks adjacent to the syenites show little metamorphic alteration (R. Ford, *pers.comm.*1979), and the primary magnetization direction of this complex (D = 314°, I = -85°) is near to but statistically different from that determined in the present study (table 1).

Most probably the overprint has to be interpreted in wider perspective as further evidence for a widespread Late Cretaceous overprinting (viscous partial thermoremanent

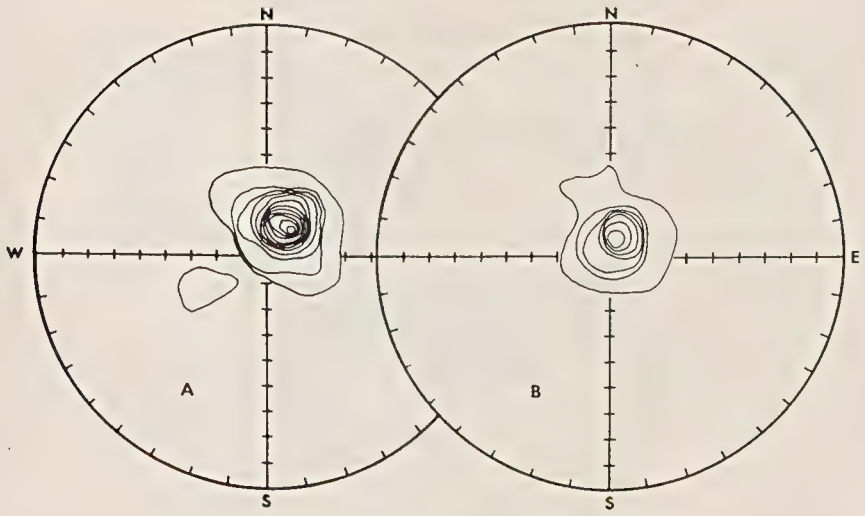

FIG. 3.- Frequency distribution of all observed NRM directions (fig. 3A, 172 specimens) and all observed characteristic directions (fig. 3B, 92 specimens). Upper hemisphere projection only. Frequency interval = 10. Present local field direction Decl. = 14°, Incl = 73°. Axial geocentric dipole field direction Decl = 0°, Incl = -62°.

magnetization [VPTRM], Briden 1965, Pullaiah *et al.* 1975) in southeastern Australia. This overprinting can be attributed to an increased geothermal heatflow during initial rift forming processes preceding opening of the Tasman Sea. Subsequent uplift and cooling resulting from the rifting, with erosion of overburden, may have preserved the VPTRM. A similar mechanism has been proposed for magnetic overprinting of rocks in the Sydney Basin, on basis of new data and a reappraisal of earlier palaeomagnetic results (Schmidt and Embleton 1980), and on basis of newly obtained apatite fission track datings (Morley *et al.* in press) from southeastern Australia. A relation with the Early Tertiary initiation of the Australia - Antarctica rifting cannot be excluded, however, for the obtained palaeopole position is not far off the Early Tertiary trajectory of this revised APWP.

On the evidence of conodont colour (Epstein *et al.*, 1977) the limestones at Ida Bay have not been subjected to temperatures exceeding 100°C (C.F. Burrett *pers. comm.*). Since the VPTRM is not removed until the rocks are demagnetized at temperatures of 400°C to 450°C for a period of about 5 minutes, it can be estimated (Pullaiah *et. al.*, 1975; Dunlop and Buchan 1977) that this low-temperature heating event must have persisted for a period in the order of 10 m.y. Widespread magnetic overprinting is therefore to be expected in the region under study.

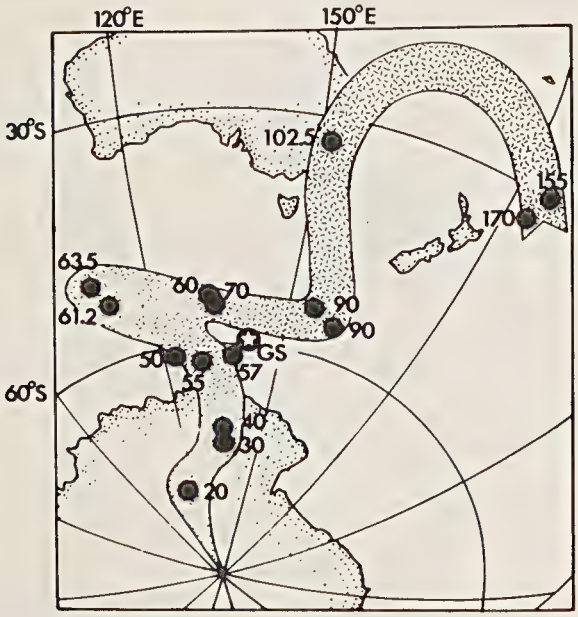

FIG. 4.- A comparison of the pole position obtained here for the Gordon Sub-group limestones (GS) with the revised APWP for Australia, based on pole positions from the Indian plate transferred to Australia according to seafloor spreading data (Klootwijk and Peirce 1979). Radiometric or mean stratigraphic ages are indicated for the latter pole positions.

ACKNOWLEDGEMENTS

Thanks are due to Dr. M.R. Banks for instigation of the project, and to Drs. M.W. McElhinny, B.J.J. Embleton, P.W. Schmidt, C.F. Burrett and W.D. Parkinson for valuable discussions.

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GORDON SUBGROUP (ORDOVICIAN) CARBONATES AT PRECIPITOUS BLUFF AND POINT CECIL, SOUTHERN TASMANIA, AUSTRALIA

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(with three text figures)

ABSTRACT

BURRETT, Clive, LAURIE, John and STAIT, Bryan, 1981 (30 ix): Gordon Subgroup (Ordovician) carbonates at Precipitous Bluff and Point Cecil, southern Tasmania, Australia. *Pap. Proc. R. Soc. Tasm.*, 115, 93-99 (with three figures). ISSN 0080-4703. University of Tasmania, Hobart, Tasmania, Australia.

The palaeogeographically and biostratigraphically important Ordovician carbonate sequence at Precipitous Bluff is at least 360 m thick. The lowest 130 m, the New River Beds, consist of bryozoan algal biosparenites of Chazyan to Blackriveran age. These beds were probably deposited in a high energy subtidal environment with minor periods of intertidal deposition. The upper 50 m of this lowest unit contains abundant *Calathium*, bryozoans and corals. The succeeding 230 m of biosparites, biomicrites, argillaceous carbonates and siltstones, the Precipitous Bluff Beds, are dominated by trilobites, brachiopods and bryozoans, range in age from Trentonian to Cincinnatian and were probably deposited in deeper water than the New River Beds.

The Prion Beach Beds at Point Cecil, five km south of Precipitous Bluff, are argillaceous micrites containing a trilobite/brachiopod fauna and include strata of Blackriveran and Trentonian age and are thus biostratigraphically correlated with the upper part of the New River Beds and at least part of the Precipitous Bluff Beds.

Vertical carbonates along New River Lagoon and sheared carbonates at Point Cecil suggest structural complications perhaps associated with a continuation of a large, possibly transcurrent fault, trending north along New River.

INTRODUCTION

This paper records the results of a reconnaissance geological survey of two palaeogeographically important areas of Ordovician carbonates. It will also form the basis for subsequent detailed biostratigraphic studies. Little geological work has been undertaken in this area mainly because of its isolation. Extremely thick vegetation makes geological work very difficult especially away from the cut tracks and no regional structural map can be produced at present.

Johnston (1888) showed 'Silurian' limestone along New River on his map and recorded a coral ('*Strombodes*') in limestone further north in the Cracroft River (State grid ref. Huon DN 6505). The next published work on the Ordovician limestone at Precipitous Bluff was that of Hughes (1957) who reported the chemical analysis of one sample and commented on its remarkable purity. No further work was carried out until 1979 when a party of the Australian and New Zealand School Exploration Society (ANZSES) led by Mr. Sean Kennedy collected small specimens at 10 m stratigraphic intervals (Banks in Hawkins 1980).

The argillaceous limestones east of Prion Beach along the western margin of Point Cecil were briefly investigated by Twelvetrees (1915), Blake (in Hughes, 1957), Banks (1962) and the ANZSES party (Kennedy in Hawkins, 1980).

The present study results from two trips to the Precipitous Bluff section (figs 1 and 2) and two trips to the Point Cecil sequence. Access to the general area is difficult but was facilitated by the use of a float plane landing in New River Lagoon and a helicopter landing (or hovering) near the Point Cecil locality allowing the removal of large specimens which could not otherwise be collected in any useful number.

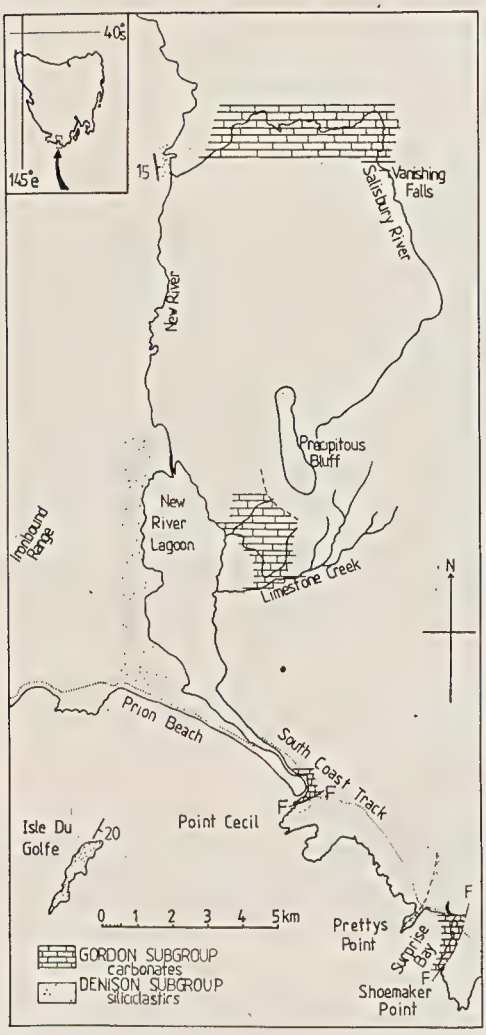

FIG. 1- Locality map showing part of Southern Tasmania. Extension of Denison Subgroup to north of Salisbury River and Isle du Golfe confirmed by helicopter reconnaissance in 1977 and 1979. F-F = Fault

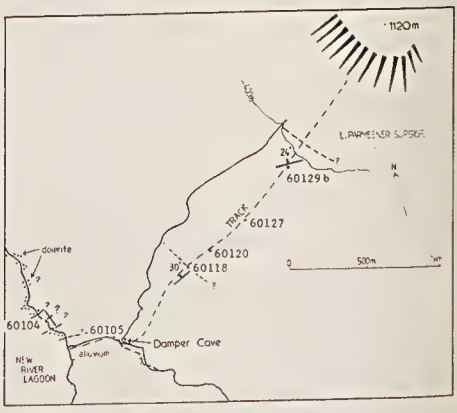

FIG.2.- Map showing position of collecting sites along walking track up Precipitous Bluf. Boundary between New River Beds and Precipitous Bluff Beds is shown just below 60118. Possible extent of the Lower Parmeener Supergroup (which contains Permian brachiopods) is indicated by dots.

PRECIPITOUS BLUFF

The southwestern flanks of Precipitous Bluf are covered by forest that ranges from fairly open to impenetrable. The section was measured along a narrow bushwalking track running up a ridge (State grid ref. Huon, DM664849-DM674861). The thick bush prevents tracing the rock types laterally. Outcrop is very poor from New River Lagoon to the base of a cliff above Damper Cave at grid ref. DM663852. Dolerite, of probable Jurassic age

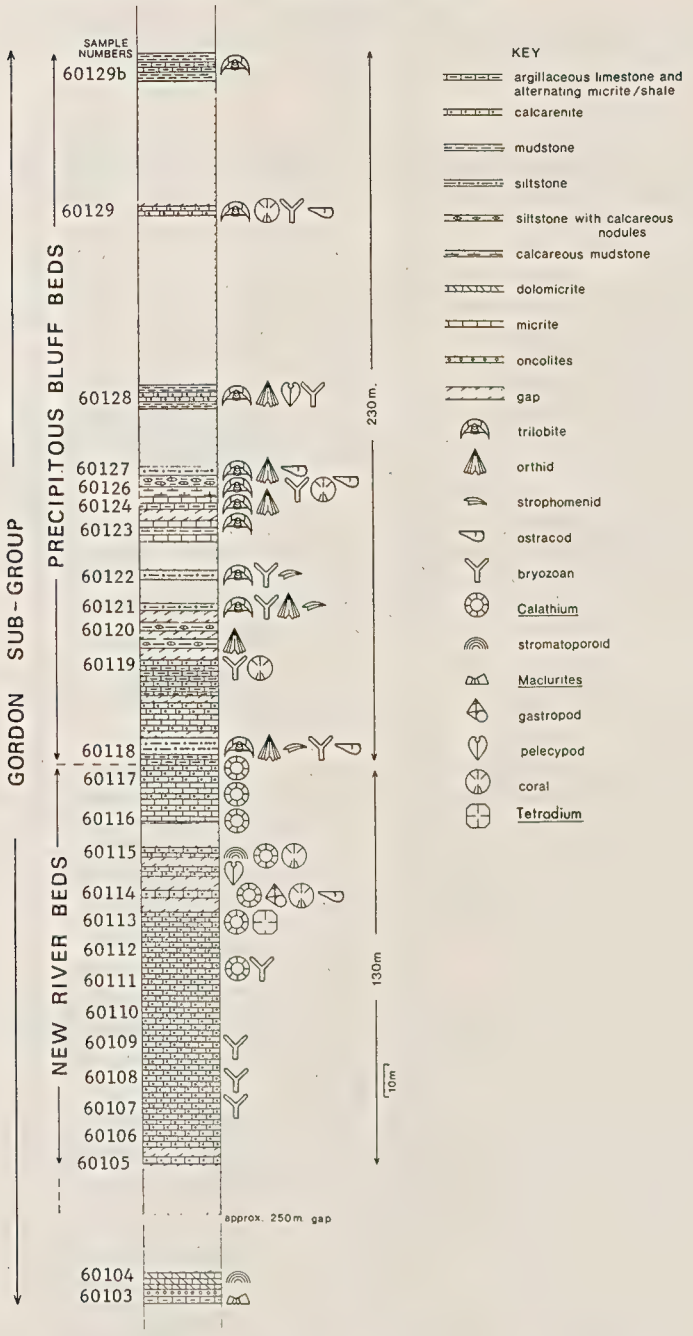

FIG.3.- Stratigraphic column of the Gordon Subgroup at Precipitous Bluff. The thickness of the stratigraphic gap (if any) between samples 60106 and 60105 is not known but could be as much as 250 m. Sample 60114 is dolointrasparite from an outcrop of vertically dipping carbonate. Sample 60115 is from the entrance (lower southern side) of Damper Cave. Sample numbers are catalogue numbers of the University of Tasmania, Geology Department rock collection.

outcrops along the eastern shore of New River Lagoon from the camp site at grid. ref. DM658851 to near the mouth of New River at DM648868. However one small outcrop of vertically-dipping limestone is present along the shore at grid. ref. DM655854.

The basal 130 m of the main sequence has excellent (about 80% outcrop) whereas the upper 230 m of the sequence contains many large stratigraphic gaps (see fig. 3). As only one narrow section was measured the sequence is not divided into formations, but rather, beds (Hedberg, 1976) are established awaiting a more complete survey of the regional geology.

Stratigraphy

Siliciclastics of the Denison Subgroup (?Late Cambrian-?Mesial Ordovician) outcrop on the western shore of New River Lagoon and along the Ironbound Range (Twelvetrees 1915) but were not investigated in this study.

Presumably the lowest 12 m of the carbonate sequence are vertically dipping and consist of a small (20 m x 12 m) outcrop on the eastern shore of New River Lagoon at grid ref. DM655854 (fig. 2). Impenetrable bush prevents tracing of this outcrop further east and no indication of facing was found. Rock types include dolointramicrudites and dolointrasparites. Five oncolites were found in one 20 mm thick bed (fig. 3). One stromatoporoid was found in the western part of the outcrop associated with several specimens of *Maclurites* sp. and other gastropods. Because of their very limited outcrop these intraclastic limestones have not been named. The restricted fauna, the abundant dolomite and the presence of oncolites suggests, by analogy with well-studied sequences elsewhere in the Gordon Subgroup, a peritidal (most likely low intertidal) depositional environment.

No conodonts were found in these beds. Elsewhere in the Gordon Subgroup *Maclurites* is found only in carbonates of Chazyan age (Banks and Johnson 1957; Banks and Burrett 1980).

New River Beds (Gordon Sub-group)

The *Maclurites*-containing carbonates mentioned above are probably separated from the basal units of the main carbonate sequence by a stratigraphic gap. The New River Beds (new name) are a sequence 130 m thick off cliff-forming, massively-bedded biocalcarenites and biomicrites outcropping on the lower western flanks of Precipitous Bluff between grid refs. DM661852 and DM665864. They dip generally towards the north, east and northeast at angles ranging from 0^{o} to 32^{o}.

The New River Beds are conformably overlain by the Precipitous Bluff Beds. Bedding averages 0.6 m in thickness, but many beds are lenticular. The New River Beds are mainly biospararenites, intraspararenites, biointraspararenites and biomicrites. Only one bed contains appreciable amounts (5%) of dolomite (sample UTGD 60113) though several horizons probably contain dedolomites.

Fauna and Flora - Fossils are difficult to see in the field due to recrystallization of the limestone, calcite veining and a covering of moss and lichen. However a major and obvious framework component (especially between samples UTGD 60111 and 60117) is the calcareous alga cf. *Calathium* which occurs as double-walled, cylindrical or conical structures averaging 35 mm in diameter. Corals including *Tetradium* and *Pycnolithus* (K. Kenna *pers. comm.*) are present in samples UTGD 60113 and 60114 respectively. In this section, bryozoa, echinodermata and various calcareous algae constitute, in varying proportions, the major bioclasts. Corals and ostracodes are significant, though minor constituents.

The biota is generally stenobiontic and in conjunction with the carbonate types suggests a generally subtidal, high energy environment. *Tetradium* and the dolomicrite of samples UTGD 60113 may represent intertidal conditions.

The basal 90 m of the New River Beds contain rare specimens of *Phragmodus flexuosus* Moskalenko, *Belodella copenhagenensis* (Ethington and Schumacher), *Drepanoistodus*

suberectus (Branson and Mehl), *Belodina monitorensis* (Ethington and Schumacher) and *Panderodus gracilis* (Branson and Mehl). This fauna suggests a Chazyan age. Sample UTGD 60116 contains *Tasmanognathus careyi* which suggests a Blackriveran age (Burrett 1979)

Precipitous Bluff Beds (Gordon Sub-group)

The Precipitous Bluff Beds (new name) are a sequence 230 m thick of thinly-bedded siliceous siltstones, calcareous shales, biomicrites and biospararenites outcropping along a ridge from grid refs DM665854 to DM673859. These beds conformably overlie the New River Beds and are overlain unconformably by fossiliferous marine rocks belonging to the Lower Parmeener Supergroup of Late Carboniferous-Permian age.

The contact between the New River Beds and the overlying Precipitous Bluff Beds is gradational but within a 3 m thickness decalcified siltstone replaces biomicrite and thereafter siltstones and shales are common in alternations with biocalcarenites and biomicrites. Bedding thickness is variable (0.5 m - 50 mm) but beds are rarely thick.

Fauna - The 4 m thick basal siltstone is decalcified, buff-coloured and lithologically very similar to the Lords Siltstone Member in the Florentine Valley (Corbett and Banks 1974).

The brachiopod fauna includes most of the species found in the Lords Siltstone including *Strophomena* sp. nov.,*Sowerbyites vesciseptus* Percival, but also contains *Ptychopleurella* sp. nov., *?Leptellina* sp., *Clitambonites* (*Clitambonites*) sp., *Skenidioides* sp. nov., *?Hallina*, *Sowerbyella* cf. *anticipata* Percival and a new genus of resupinate leptellinid. *Sowerbyites vesciseptus* and *Sowerbyella anticipata* occur in Fauna III (Eastonian) of New South Wales (Percival, *pers. comm*).

Trilobites from this level include *Remopleurides* sp., *Pliomerina* sp. and *Amphilichas* sp. (Banks, *pers. comm.*). A drepanellid ostracode (new genus A) is also common.

Conodonts are present in sample UTGD 60118 and include *Phragmodus undatus* (Branson and Mehl) and *Plectodina aculeata* (Stauffer) and suggest an Early Trentonian (Rocklandian) age.

Sample 60128 contains *Aphelognathus* sp. and sample 60129 contains *Oulodus robustus* (Branson, Mehl & Branson), *Pseudobelodina* sp., and *Aphelognathus shoshonensis* Sweet and suggests a Late Edenian-Mesial Maysvillian age.

POINT CECIL AREA

Prion Beach Beds (Gordon Subgroup) and Denison Subgroup at Point Cecil.

The argillaceous carbonates at Point Cecil to the east of Prion Beach (see fig. 2) were first mentioned by Twelvetrees (1915). Blake (in Hughes, 1957), described them as dark limestones alternating with slates. Banks (1962, p.170) recorded *Ampyx* and a cryptolithid close to *Eirelithus* from this locality and suggested a Mesial Ordovician age. The argillaceous limestones are thinly-bedded, steeply-dipping (between 75^{o}-90^{o}) and are faulted against the underlying Denison Subgroup quartz arenites. The basal limestone beds contain abundant detrital quartz. Further to the east (at DM677774 on South East Cape, 1:100 000 Sheet No. 8210) the Denison Subgroup quartz arenites are shallowly dipping (between 25^{o}-30^{o}) to the west and are, from the evidence of trough cross-bedding, right way-up. The quartz arenites are approximately 150 m thick, contain minor oligomict microconglomerates and overlie a conglomerate sequence of unknown thickness.

The argillaceous limestone outcropping along the western side of Point Cecil from grid ref. DM678775 to grid ref. CM681782 is herein named the Prion Beach Beds. Shearing and folding preclude any estimate of their true thickness but it is unlikely to exceed 200 m. Several small north-east trending transcurrent faults are present, extending for several metres approximately parallel to strike ($N60^{o}E$). The drag dip on these transcurrent faults indicates sinistral movement. About 150 m north-northeast of this shear

zone the limestones dip at 5° to the northwest.

Fauna - The Prion Beach Beds contain an abundant fauna of fragmentary trilobites. More complete trinucleid trilobites are found 20 m north of the base of these beds and are associated with a brachiopod fauna that includes *Sowerbyella* cf. *lepta* Percival. A drepanellid ostracode (new genus A) is also found at this level. Conodonts are generally poorly preserved in these beds but include *Phragmodus undatus* in a sample not stratigraphically precisely located and *Phragmodus inflexus* Stauffer in a sample 10 m above the base of the beds. The former indicates a Trentonian or younger age and the latter indicates a Blackriveran age.

CONCLUSIONS

The carbonate sequence at Precipitous Bluff is divisible into 2 main lithostratigraphic units. The lower biospararenitic New River Beds were probably deposited in a subtidal environment. These beds were deposited during the Chazyan and Blackriveran at the same time as peritidal carbonates were deposited in many other parts of the state (e.g. Ida Bay, Florentine Valley, Vale of Belvoir, Everlasting Hills: Burrett 1979; Calver 1977; Weldon 1974). The higher parts of the New River Beds were also deposited at the same time as the deeper-water Prion Beach Beds. The succeeding Precipitous Bluff Beds suggest a deeper water environment and were deposited at the same time as very shallow subtidal-peritidal carbonates were deposited at Ida Bay and in the Florentine Valley and at the same time as part of the even deeper Prion Beach Beds.

The brachiopods from the base of the Precipitous Bluff Beds include elements found in the Florentine Valley and at Mole Creek but also include species only previously known from New South Wales.

The conodont fauna also allows correlation with deeper-water sequences outside Tasmania. Several important conodonts such as *Pseudobelodina* sp., *Aphelognathus shoshonensis* and *Phragmodus inflexus*, that facilitate precise intercontinental correlation, are found in this area but have not been found elsewhere in Tasmania. Further work in this area will undoubtedly reveal an Ordovician sequence of great importance in intercontinental correlations.

The vertically dipping carbonates along New River Lagoon and the sheared and possibly overturned sequence near Point Cecil suggests structural complications perhaps associated with the continuation of the transcurrent Lake Edgar Fault along New River as suggested by Corbett (1970).

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OBSERVATIONS ON SOME TASMANIAN FISHES: PART XXVII

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(with six tables, one text-figure and one plate)

ABSTRACT

SCOTT, E.O.G., 1981 (30 ix): Observations on some Tasmanian Fishes: Part XXVII. *Pap. Proc. R. Soc. Tasm.*, 115, 101-152 (with one figure and one plate). ISSN 0080-4703. Queen Victoria Museum and Art Gallery, Launceston, Tasmania, Australia.

One new species is added to the Tasmanian list: *Ammotretis elongatus* McCulloch, 1914, from Goose Island, Furneaux Group, Bass Strait.

A detailed account, with table of dimensions, is given for two examples of *Trygonorrhina fasciata* Müller & Henle, 1841 (Rhinobatidae). It has hitherto been assumed the Tasmanian fiddler ray is the typical subspecies; however, the present paterial is determined as *T. f. guanerius* Whitley, 1932.

Other species noted are: *Dinolestes lewini* (Griffith, 1834) (Apogonidae), general specifications of a sample of eight specimens, with extensions of published meristic and morphometric ranges, *Beryx decadactylus* Cuvier, 1829, *B. decadactylus* (Günther, 1859) (Berycidae), *Paratrachichthys trailli* (Hutton, 1875) (Trachichthydae), the treatment of the last three species including detailed morphometry and various aspects of body form, with some comparison between them.

INTRODUCTION

This paper follows the general plan of others in the series. Linear measurements are given throughout unless otherwise specified in millimetres, the name of the unit commonly being omitted. The symbols *Ls*, *Lt*, *TLs*, *TLt* denote standard length, total length, thousandths (permillages) of standard length, thousandths of total length, respectively. Registration numbers denoted by Q.V.M. are those of the Queen Victoria Museum and Art Gallery, Launceston. Certain other conventions are noted in earlier contributions.

Family RHINOBATIDAE

The Handbook (Munro 1956) recognized three genera with Australian representatives, *Rhinabatos* Linck, 1790 (2 species, the Check-List (McCulloch 1929) recording 5), *Aptychotrema* Norman, 1926 (3 species) and *Trygonnorrhina* Müller & Henle, 1838 (rendered *Trygonorhina*) with 2 subspecies, the typical subspecies (type locality New Holland) in Queensland, New South Wales, Victoria, Tasmania and *Trygonorrhina fasciata guanerius* Whitley, 1932 from South Australia (type locality) and southern Western Australia (the Check-List includes a fourth genus, *Rhynchobatus* Muller & Henle, 1837, with 1 species). Of these only *Trygonorrhina fasciata* was listed for Tasmania. While no investigation appears to have been made as to the subspecific nature of the local fiddler ray — which is included in the earliest State list (the MS catalogue of Morton Allport) — it has been assumed since the recognition by Whitley of the existence of 2 subspecies that it is the eastern form categorized by him, and this is the position adopted in the Handbook, in Scott (1962), and in Scott *et al.* (1974). However, material from the estuary of the Tamar, northern Tasmania, observations on which are presented below, proves to be assignable to *T. f. guanerius*.

Observations on some Tasmanian Fishes: Part XXVII

Genus *TRYGONORRHINA* Müller & Henle, 1838

Trygonorrhina Müller & Henle, 1838 *Mag. Nat. Hist.* (Charlesw.), n.s., 2, p.90. Type-species, *Trygonorrhina fasciata* Müller & Henle. (Spelt *Trygonorhina* in PLAGIOST., 1841 on p.124 but *Trygonorrhina* on p143).

Trygonorrhina fasciata guanerius Whitley, 1932

Trygonorrhinus fasciata guanerius Whitley, 1932, p.317; cites figure 39 in Waite, 1921. Type locality: Kangaroo Island.
Trygonorrhina fasciata guanerius Whitley, 1940, p.174, fig.200 and 1964, p.34: Scott, 1954, p.106 and 1962, p.53, unnumbered fig.: Scott, Glover & Southcott, 1974, unnumbered fig.
Trygonorhina fasciata guanerius: Munro, 1956, p.15, fig.105.
Trygonorrhina guanerius Whitley, 1948, p.9.
Trygonorrhina fasciata: Zietz, 1908, p.292: Waite, 1921, p.27, fig.9 and 1923, p.47, unnumbered fig.: Lord, 1923, (1922) p.62 and 1927, p.12: Lord & Scott, 1924, pp.6,26: McCulloch, 1929, p.23 (Tasmanian reference only): Stead, 1963, pp.138,201.
Trygonorhina fasciata: Johnston, 1883, p.40 and 1891, p.39.

Accounts Without Subspecific Differentiation

In the course of an excellent description, with figure, of a young specimen of *Trygonorrhina fasciata* from Sandon Bluff, New South Wales, McCulloch (1921b, p.460, pl.38, figs 1,2) noted, in addition to sources cited above in synonymy as dealing with material from South Australia, Western Australia or Tasmania (and thus presumably relating to *T. f. guanerius*), some treatments of *T. fasciata* without subspecific differentiation but in view of the localities involved presumably relating to the typical subspecies. The more important Australian texts cited include Castelnau (1872), Macleay (1881), Haswell (1884), Ogilby (1886), Lucas (1890), Hill (1895), Waite (1899, 1904): to these the following other texts may usefully be added McCulloch (1921a), Tindale (1926), Griffith (1936). Among basic extralimital references those of Müller & Henle (1838, 1841), Duméril (1865), Günther (1870) and Garman (1913) may be mentioned. Of these accounts some adopt *Trygonorrhina*, others, including McCulloch's own, *Trygonorhina*.

Subspecific Differentiation

The brief passage in which Whitley (1932) proposed his subspecies comprises only three sentences and may profitably be quoted verbatim. "The South Australian Fiddler Ray, which has been figured by Waite differs markedly from the New South Wales form in the disposition and nature of its colour-markings. The difference may be better appreciated by comparing Waite's figure with that of McCulloch than conveyed by written description." The only other available account of *T. f. guanerius* is that of Scott (1954). As noted above, the Tasmanian form has hitherto been assumed to be *T. f. fasciata*, but on the basis of the figures by Waite and McCulloch, subsequently reproduced side by side by Whitley (1940), our specimens are identifiable as *T. f. guanerius*. After preservation of the rays in formalin for several months the pattern, originally well defined, became indistinct. On available information no morphometric distinction between subspecies can be drawn.

Other Species

For upwards of a hundred years *Trygonorrhina* had been cited as a monotypic genus; however, a second species, *T. melaleuca* Scott, 1954, also from South Australia, has now been described. It differs at sight from *T. fasciata* in coloration, having a diffuse bluish-black pattern covering back and upper part of tail to caudal fin and 4 grey bars on the hinder part of the disc.

Material

Two examples collected in the Tamar estuary in the vicinity of Ilfraville, 3 March 1980: (a) female, total length 1046 mm standard length (to origin of caudal) 893 maximum disc width 474, I. Sutcliffe (Q.V.M. Reg.No. 1980/5/26), (b) female, total length 1139 mm standard length 994 maximum disc width 490, R. Hunt (Q.V.M., Reg.No. 1980/5/57).

Dimensions; Methods of Determination

Hubbs and Ishiyama (1968), extending the recommendations of the methods for the study of bony fishes by Hubbs and Lagler (1958, 1964) and in part those previously proposed and followed by Ishiyama (1958) for rays, set out a series of measurements and defined the conventions in accordance with which it is recommended they be made. A basic proposition is the following: "Each determination is taken point-to-point, as this procedure is far more objective and precise than measuring projections onto an imaginary line supposedly parallel with some axis." This procedure represents a radical departure from the general practice long observed in Australian and in the majority of overseas texts in respect of those measurements that can appropriately be made between parallels, e.g. directly between normals to the general anteroposterior axis of the fish — see, for instance, the "set of standard measurements for comparative and biometric studies of Australian sharks" devised by Whitley (1943 p.114) and extensively employed in his papers. In offering their recommendations Hubbs and Laglar observe "We hope that these methods will meet with the acceptance afforded the methods proposed by Hubbs and Lagler (1958, 1964) for the systematic study of bony fishes"; and this hope has found general fulfilment. It is here suggested such acceptance of the proposals (in particular the general point-to-point specification) may perhaps have been a somewhat uncritical one; some considerations regarding the appropriateness of the two methods of measuring and reporting the magnitude of some morphological features are here noted. The relative merits of measurements made point-to-point and those made between parallels may conveniently be examined in respect of two criteria, (a) the ease of operation and the precision, objectivity and reliability of specification, (b) the general biological significance of the magnitudes recorded.

Consider first ease, precision and objectivity. It is evidence that for the majority of measurements the point-to-point technique is indeed simpler and easier to perform and is calculated to yield an objective and precise result. It may be questioned whether in the case of the dozen or so measurements listed by Hubbs and Ishiyama that include the specification "from snout tip" point-to-point measurements made with dividers are likely to be as truly objective as those taken between parallels with the aid of a measuring board (the tip of the snout being objectively determined in the latter method by direct contact with the anterior board, the former involving some subjective decision as to the precise point to be treated as the tip of a part of the body commonly rounded in two planes). In respect, however, of reliability in the sense of uniformity of magnitude (i.e., as with reported measurements in general, relative magnitude; reported values conventionally being given as proportions, usually as percentages or millesimals of a standard magnitude such as maximum disc width - adopted by Hubbs and Ishiyama - or standard length) among members of a sample, hence as a systematic index, the point-to-point method is open to theoretical objection. Consider the listed measurement No.33, "*Prenarial length*: from tip of snout to nearest point on outer rim of nostril". If taken between parallels this involves only one axis that is the subject of variation, namely, the general anteroposterior axis of the ray. If taken point-to-point two axes subject to variation are involved, namely, the general anteroposterior axis and the transverse axis. With a large series of specimens at hand it would be instructive to compare the coefficients of variation of prenarial length yielded by point-to-point and between-parallels measurements. (Experience indicates that in species with a markedly sinuous outline in the anterior half of the disc individual variation in disc width here may be not inconsiderable; with this internarial distance may be correlated.) Further, in a measurement such as No.31, preocular length, there is introduced, at least as a formal component, a third plane of variation, that of depth.

The significance of certain dimensions and their mode of determination may next be considered. In the course of these contributions it has repeatedly been found for a variety of species among teleosts, selachians and (less extensively investigated) batoids that with measurements taken between parallels normal to the general anteroposterior axis

dimensions such as length of head, length to vent, lengths to origins and terminations of vertical fins, calculated as relative to standard length, exhibit the exponential relation $L = b\ N^K$, where L = length to point, N = a natural number. It is difficult to believe that such formulations do not point to the existence of certain basic nodes of growth disposed linearly along the primary anteroposterior axis of the fish (*s.l.*). The location of such nodes so disposed would clearly be less precisely specified by point-to-point measurements involving the additional component of depth. Among rays, sharks and bony fishes the first, in view of their depressed form, would in general be least subject to such extra variation, while in deep-bodies forms the differences between the two types of measurement may be considerable. In a specimen of the moderately deep *Centroberyx affinis* (Günther, 1859) at hand the point-to-point measurements of length to dorsal origin, length to anal origin are 1.27 and 1.07 those taken between parallels. A more pertinent example is provided by a ray with an elevated dorsal profile such as *Myliobatis australis* Macleay, 1881, in a specimen of which with a total length of 1225 mm and a disc width of 990 mm the preocular length measured between parallels was found to be 65 mm, measured point-to-point 128, or virtually twice as much. The considerable difference between the figures just noted directs attention to a further significant point of difference between the two methods of measurement when the results are considered as applicable to a series of dimensions, namely, the relative divergence between the two data will not be constant for all items but will be subject to variation determined by the body form.

Where it has seemed expedient dimensions of the present specimens are recorded by both methods of measurement, thus making them directly comparable with those noted in accounts already published of this (and in general other Australian) species and with those specified in accordance with the more recent system.

Dimensions; Present Material

Published accounts of the typical subspecies provide no good series of measurements, but more than a dozen dimensions of a female *Trygonorrhina f. guanerius* from St Vincents Gulf, South Australia have been recorded by Scott (1954). Two sets of measurements are here presented. Apart from a couple of omissions the first represents the schedule of measurements of external features proposed by Hubbs and Ishiyama, absolute dimensions (mm) being recorded only for the first two entries, total length disc width, the remainder being given as millesimals of maximum disc width. The second set covers some additional morphological features not noticed in the Hubbs-Ishiyama schedule, in particular those here investigated in the section Aspects of form. In order to permit direct comparison of proportional relations here specified with comparable formulations for other species previously reported in these contributions, dimensions continue here to be expressed as millesimals of standard length, i.e., length to origin of more anterior caudal lobe ((a) 893 mm (b) 994 mm), rather than as millesimals of maximum disc width ((a) 474 mm (b) 490 mm) as in the preceding set. In the case of exponential relations of the form $Y = b\ N^K$, with N the serial number of a metameric or otherwise repetitive structure, here regularly rectified as $\log Y = k \log N + \log b$, conversion from a standard length to a disc width metric is obtained thus: the slope (k) is constant, the intercept ($\log b$) is transformed by multiplying its antilogarithm by absolute standard length, dividing by absolute disc width and taking the antilogarithm. The statistical significance as measured by t of course remains unaltered.

Hubbs-Ishiyama schedule, dimensions from No.3 onward as millesimals of maximum disc width.

1 Total length 1046 mm, 1139 mm

Disc measurements

2 Disc width 474 mm, 490 mm; 3 disc length 1014, 1020; 4 anterior projection 608, 571; 5 trunk length 647, 646; 6 mouth to tail 1215, 1238; 7 precaudal length 992, 1087.

Tail measurements

8 Tail length 1018, 1097; 9 tail width, end P_2 179, 179; 10 tail depth, end P_2 116, 122; 11 tail width, origin D_1 174, 173; 12 tail depth, origin D_1 105, 107; 13 predorsal length 100, 168; 14 D_1 origin to tail tip 918, 929.

Fin measurements

15 D_1 basal length 124, 120; 16 between D bases 211, 241; 17 D_2 basal length 122, 118; 18 postdorsal length 939, 989; 19 D_1 vertical height 173, 180; 20 D_2 vertical height 178 176; 21 C vertical height 86, 84; 22 lateral fold length 960, 929; 23 lateral fold width 19, 15; 24 behind lateral fold 127, 122; 25 between front tips, P_1, 970, 980; 26 P_2 width 222, 235; 27 P_2 length 396, 367 (mean of left and right); 28 anterior P lobe 141, 125 (mean of left and right); 29 clasper lengths (not here applicable) —.

Head measurements

30 Head length 543, 582; 31 preocular length 264, 253; 32 preoral length 253, 245; 33 prenarial length 190, 194; 34 internarial distance 179, 184; 35 nasal curtain length 92, 86; 36 nasal curtain width 194, 196; 37 between nasal fimbriae 179, 178; 38 between rostral pores —, —; 39 mouth width 148, 139; 40 eyeball length 36, 35; 41 between orbits 110, 112; 42 between spiracles 156, 155; 43 spiracle length 82, 86; 44 over 1st gill slits 418, 451; 45 prefontanelle length 385, 374; 46 anterior concavity 44, 39; 47 anterior convexity 143, 86; 48 posterior concavity 127, 78; 49 posterior convexity 137, 61.

Between disc spines

50 Left-right scapulars 158, 168; 51 spines, one side 316, 337; 52 over prescapulars 59, 61; 53 pre- to mediscapular 76, 87; 54 behind last scapular 46, 47; 55 over lumbar spines 348, 408.

Some additional dimensions, all measured between parallels and recorded as millesimals of standard length, smaller specimen cited first. Lengths to gill slits 1-5 (mean length on right and left sides as measured, the two values agreeing within 1.4% or less) 183 198 214 229 242, 191 209 226 243 258. Intervals between gill slits (inner ends) 181 172 159 145 138, 171 159 148 134 128. Lengths of gill slits (direct from tip to tip) 19.6 22.0 23.0 24.6 18.2, 23.1 24.8 25.7 26.1 17.8. Length to vent (middle) 489 512, length of vent 26 28. Length to origin of first dorsal 660 674, of second dorsal 839 849. Width of disc at 12 equal intervals along anteroposterior axis from tip of snout to and including posterior border 172 291 370 436 490 520 531 521 496 461 396 274, 160 258 337 400 456 486 493 479 458 425 372 241 (in view of the general lability of the disc in the region the last measurement of each set cannot be regarded as having a high degree of reliability). Preocular length 112 106 (*cf.* point-to-point 130 123).

South Australian Female Specimen

A description of a female of this subspecies of total length 864 mm, disc width 374, disc length 357, from St Vincent's Gulf, South Australia (Scott 1954, p.108) contains a dozen other dimensions (recorded in mm, here rendered as thousandths of disc width): tail 502, its width at posterior insertion of ventrals 86, eye 28, interorbital 71, preocular length 108, preoral length 116, width of mouth 91, width of internarial valve 96, length of ventral 86, first dorsal height 102, its distance from origin of tail 76, second dorsal height 89, its distance from origin of tail 211. The method of measurement is not specified but it may be presumed distances are measured between parallels.

General Features

The following account is based primarily on the larger individual, *Ls* 994 mm, entries relating to the smaller, *Ls* 893 mm, being in parentheses; all dimensions are here recorded as thousandths of standard length (*TLs*). As far as is relevant and expedient it follows, with some extensions, the description (with figures of dorsal aspect and oral region) by McCulloch (1921b) of a young specimen of *T. fasciata fasciata* 380 mm long from off Sandon Bluff, New South Wales.

Skin of upper surface of disc and tail more or less velvety, that of lower surface in general hard, smooth, glossy. On most of lower surface minute subcircular denticles occur in regularly arranged rows, some 50-60 cm^{-1}, their interspaces modally less than their diameters; on most of upper surface they are of two or more sizes, less regular in form, less evenly disposed. On dorsal surface of disc from immediately behind scapular arch at 1.8 (1.8) of disc length to origin of second dorsal (first dorsal, McCulloch) a band of small but clearly visible tubercles, set rather thickly, 15-20 cm^{-2}, width at origin 125 *TLs* (100) at insertion of first dorsal 50 (56) of second dorsal 25 (20).

An irregular patch of minute tubercles, seen with difficulty, below and behind eye (not mentioned by McCulloch or Scott). A row of tubercles along median line of back, first few poorly developed, largest, 11-12 long 3-4 high, before first dorsal, base modally elliptical (major axis anteroposterior) in some cases becoming more or less rounded, surmounted by a short straight keel or ending in a knob or blunt point, the whole structure enveloped in skin; first at 60 (67) behind eye, 2 others before pectoral arch, 1 on arch, 14 before first dorsal origin, 3 (0) in anterior two-thirds of interdorsal, total 21 (18) (18 before first dorsal, McCulloch; 17 + 2 between dorsals, Scott). A rather massive but only obscurely differentiated tubercle or knob at each end of the elevated supraorbital ridge, distance between front and back rather more than half that between right and left, which is the same for the anterior and posterior pairs. On either side of the median line of tubercles 2 scapular spines, the anterior one slightly in advance of the median tubercle situated on the transverse ridge of the arch, the posterior between the levels of this and the next median tubercle, direct distance between right and left anterior subequal to that between four successive median tubercles here, that between posterior a trifle less. Externad of these spines three on each side (in (a) tending to form a subcontinuous ridge) the anterior about four times as far in advance of ridge of arch as the front one of the inner series, the middle about level with the second inner, the posterior between the levels of the first two postscapular median series; mean distance apart of these outer spines about twice that between inner spines, this distance, however, increasing slightly from first spines to last. (A double row arranged in pairs, McCulloch; two rows of four on each side, Scott.)

Disc well rounded, anterior half rather less pointed than in figures by McCulloch and Waite; differing markedly in the snout region in our two specimens — in (b) outline here sloping evenly forward and very obtusely pointed (much as in illustrations cited), in (a) at round about one-third of the preocular length the width of the outline decreasing abruptly with formation of a well-marked median lobe, its length almost one-third its width, its anterior margin close to one-third of a circle (see below, Aspects of Form). Width of disc just less than, 0.996 its length (just greater than, 1.03) ("a very little narrower than long", McCulloch; 1.05 length, Scott). Width-length equations of both discs are given below. Ventrals wholly separate, subquadrangular, anterior segment of outer border approaching linear, its length about 110 (120), angle broadly rounded, posterior segment slightly convex subequal in length to anterior, tip acute, inner border gently bisinuous, its length 100 (70); greatest width a little more than twice in the length (length less than combined width, McCulloch); distance between anterior insertions of fins subequal to that between insertion and tip (length greater, McCulloch) or about 5 times that between insertion and vent, distance between posterior insertions 3.6 (2.9) in that between anterior; tip of pelvic extending behind hind border of pectoral by about 150 (135).

Preocular length from snout tip to eyeball between parallels 9.57 (9.70) or point-to-point 8.17 (9.08) in length of disc, and, parallels 2.95 (3.70), point-to-point 2.52 (3.08) width of disc at level of eyes. Eyes fairly well elevated above level of snout tip, with strong supraorbital ridges, the space between them flat but sloping somewhat down and forward longitudinally, very concave transversely. Eyeball 2.5 (3.0) (McCulloch, 3½; 2.5, Scott) in interorbital, 4.5 (4.3) in preocular length, here measured between parallels (McCulloch, 5; 3.9, Scott). Spiracle large, about one-sixth longer than eye, extending forward to just in advance of middle of eye, pointed in front sinuously rounded behind; from its posteroexternal border there projects a stout fleshy structure; viewed from above it constitutes an upwardly convex subtriangular process, its basal width one-fifth length of spiracle, its length half as great again; viewed laterally it is seen to be subtended lengthwise along the middle by a subtriangular fold, the basal (posterior, attached) border of which is subequal to the width of the external base of the structure.

Mouth cleft almost straight at most slightly proconvex, its width, here measured across tooth band of upper jaw, 0.55 (0.60) preoral length ("almost three-fifths of", McCulloch; 0.84, Scott), or 4.47 (5.06) in disc width here. In the larger individual a simple groove, its length about one-seventh width of mouth, curves back from either end

of hind lip; in the smaller individual the groove on the left side, but not that on the right, continues round and back to trace out a blunt recurved process, which, however, achieves no independent existence as a three-dimensional structure, remaining merely outlined on the general plane here by the continuous groove. This dermoglyph is evidently one of the prominent and decidedly larger paired features shown in McCulloch's figure, of which that on the right of the illustration could perhaps be mistakenly interpreted as a process of the nasal curtain. External to the mouth cleft and, except very briefly below the dermoglyph, to these grooves a continuous or subcontinuous groove curves back from about the level of the rictus on either side, then turning inward and running subparallel to the mouth, but being slightly proconcave, thus forming a large transversely elongate loop; width of groove 1.1 that of mouth, greatest distance behind lower lip 0.3 its own length. Within this loop, subparallel to its hind border, from which it is distant about half as far as from mouth, a more or less straight groove, its length approximately equal to half mouth width.

The narial region differs considerably in general appearance from that in the figure by McCulloch, the differences, however, being in part only a question of proportion. Thus: distance from level of outer border of upper rim of narial opening to level of hind border of nasal curtain (nasoral valve, internarial valve) much shorter relative to width of curtain, about 2.5 in latter, in our material 2.1 (2.1); length of opening together with its associated fringing fold much greater, about 0.7 (cf. about 0.4) curtain length, its greater length being largely accounted for by the great width of the fringing fold, about two-thirds (*cf.* about one-third) its width; anterior border of naris, broadly rounded in the Tasmanian specimens, figured as bluntly pointed; hind border of curtain, virtually coextensive with mouth, shown slightly and evenly proconvex, is slightly sinuous in (a) with approximately the same degree of overall curvature but almost linear in (b). Some distance below the general surface a fold crosses the upper half of the opening (wall bordering it externally undercut), its lower border continuing inward behind the curtain to constitute the forwardly convex anterior wall of the olfactory sac, the outer half of the posterior wall being formed by an elongate curved process representing a continuation of the external fold flanking the opening behind, the inner half by a separate proconcave fold; distance between hidden pointed inner ends of the right and left sacs about one-fourth greatest width of curtain, which at this level is broadly attached by a transverse base; within the sac, the large fusiform olfactory organ with the usual system of complex folds extends outwards beyond the external outer margin of the nasal opening.

Tooth complement in upper jaw a whitish band about one-tenth as wide as long, surface moderately convex fore and aft curving down most rapidly behind; extending across virtually whole extent of mouth cleft, anterior border rather strongly posterior slightly proconvex; teeth very small, lozenge-shaped, contiguous forming a smooth pavement with round about 70 rows from left to right, up to about 16 from back to front. In lower jaw extending on to external surface in a band, anterior border slightly proconvex posterior more decidedly proconcave, about one-tenth as wide as long, visible length 0.7 that of band of upper jaw; up to about 10 teeth in an oblique anteroposterior row.

Gill slits of moderate size, modally presenting a simple curve or briefly recurved at inner end, 5th sigmoid; length to 1st 0.39 (0.40) to 5th 0.52 (0.53) length of disc ("well behind middle of pectoral disc", McCulloch; slightly behind, Scott); anteroposterior extension of series subequal to direct (oblique) distance of 1st from angle of mouth; widths between 1st pair 2.88 (2.73) between last pair 3.82 (3.72) in disc widths at respective levels. (For further specifications of gill slits see section, Aspects of Form.)

Tail as measured between parallels from middle of vent to origin of caudal fin slightly shorter than body, 488 *TLs* (a little longer than, 502 *TLs*) ("a little longer", McCulloch; 1.01, Scott: tail in Scott includes, and in McCulloch probably includes, caudal fin); stout, its greatest depth two-thirds its greatest width or somewhat greater than (McCulloch, equal to) interocular width or 1.3 (1.1) width of mouth, lower surface flat, lateral strongly dorsal moderately convex, trenchantly divided in respect both of

character of surface and colour into upper and lower elements by the well-developed lateral fold, originating nat far behind commencement of free tail at 55 (45) in front of first dorsal origin, traceable back, gradually lapsing to extinction on caudal fin, right to level of end of vertebral column, located in advance of tip of fin by 55 (62) ("lost at the base of the caudal", McCulloch).

Dorsal fins located in middle one-third of the total free tail with caudal fin, set rather close together, the interval between them 1.2 (1.1) height of the taller; fins much similar in size and form, first a trifle taller; in the first dorsal the slightly convex anterior border is 1.4 (1.4) the almost straight distal border and 4.6 (4.6) the slightly concave posterior, in second dorsal 1.4 (1.5) and 5.1 (5.4); bases subequal; in first dorsal height 1.8 (1.5) base, in second 1.1 (1.2). Caudal well developed, its length between parallels being 12.7 (14.6) in total length, or 1.3 (1.6) vertical height of first (taller) dorsal, paddle-shaped, upper border only very slightly convex, distal and ventral borders not sharply differentiated, together presented more or less a single sweep, 2.3 (2.1) as long as wide, lower lobe inserted shortly in advance of upper.

A feature not noted by McCulloch, Whitley or Scott and not observed in any other Tasmanian rajids at hand is a pair of grooves on the ventral surface, one on either side of the median longitudinal line, lying behind the gill slits by about one-tenth of the interval between the last pair of these. Each groove comprises a sinuous transverse segment, its length about five-sevenths of mouth width, and an outwardly convex segment the oblique arc of which slopes backward and outward, its length about half as great again as that of the transverse segment; at their anterior ends the grooves approach each other to within 3-4 mm, while the distance between their posterior extremities is 170 (190) *TLs* or 0.6 of disc width here. Each groove is divided into cells, longer than wide, about 5 in 20 mm, the partitions between which do not in general extend quite up to the level of the general external surface. From its structure this feature would seem probably to be of a sensory or secretory nature.

Aspects of Form

1. Shape of disc. In both individuals the disc overall is broadly rounded attaining its greatest width at seven-twelfths of its length from the tip, the front half being in the larger noticeably, in the smaller somewhat, less convex than the hind half. In the larger disc the tip is quite evently and rather bluntly rounded, the whole outline presenting a flowing curve, closely approximating those found in the figures of this subspecies by Waite (1921 unnumbered on p.27) of *Trygonorrhina fasciata* Müller & Henle, 1841, by McCulloch (1921, pl.38 fig.1) and of the South Australian *T. melaleuca* Scott, 1954 by its author (1954, fig.1); this may well be the modal configuration. In the smaller disc the outline in the anterior one-twelfth is more complex: at the hind boundary of this segment, 39 mm (44 *TLs*) behind the tip, the width is 172 *TLs* units; after continuing forward in the same general sense as the curve behind it for a distance of some 15 mm, representing a direct advance of some 10 mm, the disc rim on either side abruptly approaches a direction normal to the general anteroposterior axis, the least width now being only about 105 *TLs*; arising from the short right and left platforms thus established the remainder of the anterior outline takes the form of a clearly differentiated evenly rounded arc, its chord about three and a half times its length. It may be observed that in rays in general variability of outline tends to be more pronounced, at both the specific level (where it may be diagnostic) and the individual level, in the anterior than in the posterior moiety of the disc, the latter commonly being or approximating a simple conic curve.

With eleven measurements of width taken at equal intervals between the tip and the level of the hindmost point on the posterior border the disc outline is very satisfactorily specified in each case by a second degree polynomial. The data below are for widths as thousandths of "standard length" (to base of caudal fin), the larger individual noted first. Initially twelve measurements were made. However, that representing the distance between the most posterior points of the disc on either side was in the event rejected — an accurate determination being found to present some difficulty in view of the general lability of the disc in this region; further, calculation with twelve variates

demonstrated the inability of a second degree or even a third degree polynomial to cope satisfactorily with the sharp decrease in magnitude of the width here (thus for the smaller specimen predicted *TLs* values for the eleventh and twelfth widths were 379, 387, measured 396, 274; a striking contrast to the accurate predictions of equations for eleven variates). The grid of measurements at twelve equal intervals between anterior and posterior boundaries of the disc here adopted misses the pronounced local variation in outline just behind the tip in the smaller ray.

$W = 44.73 + 124.11N - 8.6154N^2$. Calculated (measured) widths 160(160) 258(258) 340 (337) 403(400) 450(456) 479(486) 491(493) 486(479) 464(458) 424(425) 367(372). R 0.9978.
$W = 54.15 + 133.12N - 9.2822N^2$. 178(172) 283(291) 370(370) 438(436) 488(490) 519(520) 531(531) 525(521) 500(496) 457(461) 395(396). R 0.9994.
The addition of a term in N^3 yields only a marginally better fit (F 0.496 0.992).

In addition to some obvious difference of form already noted some other features distinguish the discs. With dimensions made directly comparable by being expressed as millesimals of standard length it is found that of the smaller example is longer relative to general length (524 *v.* 495) and also is relatively wider (172-531 mean 424.9, 160-493 mean 392.9). Without examination of further material it cannot be determined whether these variations are size-determined or are merely individual.

Not only do the specimens differ in overall relative length and relative width, they exhibit also variation in the proportional widths of their anterior and posterior sections, as is apparent from the subjoined equations for, first the outline from the tip to the maximum width, secondly, that from (and including) the maximum width to the posterior border (dimensions as *TLs*, larger individual first).

Front half:
$W = 43.14 + 124.71N - 8.50N^2$. R 0.9997. (Percentage variation of predicted from measured widths 0.0-1.4 mean 0.46).
$W = 49.43 + 136.16N - 9.631N^2$. R 0.9996. (Percentage variation 0.0-2.7 mean 0.92).

Hind half:
$W = 489.28 + 8.71N - 6.4286N^2$. R 0.9999. (Percentage variation 0.0-0.7 mean 0.16).
$W = 520.00 + 18.43N - 8.5714N^2$. R 0.9987. (Percentage variation 0.2-0.9 mean 0.47).

Hence while the sample widths both in the anterior halves of the two discs and in their posterior halves are strongly correlated, specimen with specimen (r 0.9991 0.9986, z 3.835 3.645) the parameters of the regression of one individual on the other differ noticeably when front and hind sections are compared. With the data for specimen (b) of *Ls* 994 mm plotted against those for (a) of *Ls* 893 mm the best straight lines are as below:
$Wa = 0.95Wb - 10.62$; t 51.712***.
$Wa = 0.88Wb + 20.35$; t 33.122***.

2. Head, length to vent, standard length (head is here taken as length to 5th gill slit, standard length as length to origin of anterior (lower) caudal lobe). In a loglog plot these three dimensions are significantly linear on integral 1 2 4. With lengths as *TLs* the best straight lines are as below (here, as customarily in these studies, minimization of the sum of the squares of deviations is performed for the logarithmic, not the arithmetic, deviations — in general it is found the two solutions do not lead to a significant difference in the formulation).
$\log L = 0.9429 \log N + 2.4237$; t 23.206*; calculated lengths, *TLs*, 269 510 980.
$\log L = 0.9722 \log N + 2.4153$; t 218.143**; 260 511 1 015

3. Origins of first dorsal, second dorsal, caudal fins. These dimensions are linear on a loglog plot on 8 9 10.
$\log L = 1.8685 \log N + 1.1347$; t 17.416*; calculated lengths, *TLs*, 664 827 1 007.
$\log L = 1.7715 \log N + 1.2320$; t 15.067*; 679 836 1 008.

4. Transverse distance between gill slits. It has been found in some unpublished investigations on sharks and rays that, in a loglog context, certain measurements involving gill slits, comprising length to length of and transverse distance between slits, are specifiable in terms of the sequential numbers of the slits. However, it would appear that in general one or other of the terminal slits (1st or 5th) stands outside the pattern presented by the remainder. In the case of the present material, when the transverse intervals (I) between slit pairs 1 2 3 4 5 are plotted on loglog paper on their reverse serial numbers (N') 5 4 3 2 1, variates 4 3 2 1 are effectively collinear while slit 1 on 5 lies outside the series. For the relevant variates the best straight lines are:

Log I = 0.2393 log N' + 2.0905; t 33.754***; calculated intervals, *TLs*, 145 160 172 181.
Log I = 0.2618 log N' + 2.0473; t 20.478**; 134 149 160 170.

5. Lengths to gill slits. With lengths (between parallels) from tip of snout as measured on right and left sides averaged (lengths for the two sides differing by a maximum of 1.4%, mean < 1%) it is found that in a loglog plot the lengths to slits 2-5 on their serial numbers are linear; with length to slit 1 outside the line.

Log L = 0.2151 log N + 2.2798; t 3.994 (just short of significance at P 0.05; 4.303); calculated lengths, *TLs*, 221 242 257 269.
Log L = 0.2358 log N + 2.2484; t 15.181**; 209 230 246 259.

6. Lengths of gill slits. In a loglog plot the lengths of slits 1-4 are linear on their serial numbers; with length of slit 5 well outside (below) the line of positive slope.

Log L = 0.1579 log N + 1.2921; t 9.908*; calculated lengths, *TLs*, 19.6 21.9 23.3 24.4.
Log L = 0.08808 log N + 1.3661; t 12.822**; 23.2 24.7 25.6 26.2.

7. Overall curves for gill slit variates. In formulations above it has been shown that the transverse interval between, the lengths to and the lengths of the gill slits are functions in a loglog plot of the serial numbers of the slits, with one of the terminal members of the series (1st or 5th slit) lying outside the specification. In view of their very wide occurrence such simple magnitude-number relations are clearly worthy of record even in a curtailed series. However, the question of the overall curves for the complete populations is itself a matter of separate interest, and polynomials of the third degree are found to provide very precise specifications of the data for all 5 slits, the relevant arithmetic (logarithmic) magnitude, expressed as millesimals of standard length, here being associated with their ordinal numbers. The relevant equations, together with values predicted by them and an indication of goodness of fit, are presented in table 1.

Coloration

The ground color of the upper surface is reported as varying "from sandy to light brown, yellowish, dark brown, even greyish at times, according to the immediate environment" (Stead 1963).

In both our specimens as preserved the ground color of the upper surface of the disc and tail is almost uniform dark somewhat greenish brown approaching black; pelvics a little lighter distally; dorsals dark elephant, a trifle lighter along distal margin, caudal concolorous with dorsals except area occupied by vertebral column which is concolorous with general dorsal surface. When first examined both individuals presented an elaborate pattern of bands of a light color approximating lilac, bordered along each margin by a narrower band of very dark brown, disposed along and symmetrically on either side of the median line — somewhat suggestive of the scroll-like holes and purflings in the belly of a violin, whence the vernacular name "fiddler ray" — the general arrangement being in close agreement with that shown in the figure (Waite 1921) of *T. fasciata guanerius*, departing clearly from that in the standard figure (McCulloch 1921a) of the typical subspecies. The markings have almost disappeared in (b) but most are still traceable in (a), main band greyish, modally some 10 mm wide, bordering lines usually of even width throughout (modally about 4 mm) dark brown.

TABLE 1

Trygonorrhina fasciata guanerius WHITLEY, 1932

Measurements involving gill slits defined by $Y = A + BN + CN^2 + DN^3$, where N = serial number of slit; dimensions as millesimals of standard length. Two specimens from the estuary of the Tamar River, northern Tasmania, (a) standard length 893 mm (b) 994 mm.

Feature	Transverse interval		Length to slit		Length of slit	
Specimen	(a)	(b)	(a)	(b)	(a)	(b)
A	179.00	176.00	170.20	173.50	22.28	27.10
B	9.05	—1.19	11.15	17.41	5.71	—7.68
C	—8.037	—4.607	1.892	0.322	3.735	4.461
D	0.91677	0.58333	0.24990	0.08333	0.55000	0.65832
R	0.9999	0.9987	1.0000	1.0000	0.9694	0.9887
Calculated (measured) values	181(181)	170(171)	183(183)	191(191)	19.7(19.6)	23.2(23.1)
	172(172)	160(159)	198(198)	209(209)	21.4(22.0)	24.3(24.8)
	159(159)	147(148)	214(214)	226(226)	23.9(23.0)	26.4(25.7)
	145(145)	135(134)	229(229)	243(243)	24.0(24.6)	25.6(26.1)
	138(138)	128(128)	242(242)	258(258)	18.6(18.2)	17.9(17.8)

The overall color of the ventral surface is ivory. In both individuals the disc is bordered in its hind half by a dark brown strip, regularly widening backward, up to about 60 in (a); the color in each case lightening inward; in (a) more or less continuously to end in a scalloped line of light grey, in (b) in two more or less distinct bands: in (b) this lateral darkening becomes apparent behind level of mouth, in (a) it is traceable forward virtually to tip of snout, here only 2-3 mm wide. Both examples present some dusky smudging, in (b) in scattered and quite irregular lines and patches on hind half of disc and front half of tail, in (b) chiefly as a large roundish smoky area surrounding vent and a smaller oval area at base of tail. In the larger specimen about five score of conspicuous black spots or splashes, mostly 3.5 mm in diameter a few much smaller, are scattered over the whole prenarial area, with half a dozen extending back to just behind level of mouth: in the smaller there are no more than ten, decidedly lighter, just behind left half of mouth.

FAMILY BERYCIDAE

Of the five Australian fishes referred to this family in the majority of texts from the Check-List (McCulloch 1929) onward one only appears in any Tasmanian list, *Centroberyx affinis* (Günther, 1859) — by Johnston (1883, 1891) listed as of the genus *Beryx* Cuvier, 1829, by Lord (1923, 1927) and Lord & Scott (1924) as of the genus *Trachichthodes* Gilchrist, 1903 and referred to the family Trachichyidae (the members of which as it is currently recognized have II-III (modally III) anal spines whereas the berycids characteristically have IV, occasionally III-IV). This deepwater species, recorded from all Australian States (and New Zealand) was noted by Johnston as rare in Tasmania. The distribution of the second local species, *Beryx decadactylus* Cuvier, 1829, is given in the Check-List as Victoria and Bass Strait but Tasmania is expressly cited along with Victoria in the Handbook (Munro 1958); it has a wide distribution, being also met with in both the Pacific and Atlantic oceans.

Observations on some Tasmanian Fishes: Part XXVII

KEY TO BERYCIDAE RECORDED FROM TASMANIA

Dorsal with 7 spines, 11-12 rays. Anal with 12 rays, base (sloping) subequal to base of second dorsal. Red above cream below, with longitudinal red streaks ..... *Centroberyx affinis*

Dorsal with 4 spines, 16-19 rays. Anal with 28-29 rays, base (sloping) about 1½ base of second dorsal. Uniform carmine ..... *Beryx decadactylus*

Genus *BERYX* Cuvier, 1829

Beryx Cuvier, 1829, REGN. ANIM., ed.2, p.151. Type-species, *Beryx decadactylus* Cuvier.

Beryx decadactylus Cuvier, 1829
(Fig. 1)

Beryx decadactylus Cuvier, 1829, HIST.NAT.POISS., 3, p.222. Type locality: unknown.
Beryx decadactylus: Günther, 1887, p.33, pl.6 (skeleton): McCulloch, 1929, p.130: Whitley, 1964, p.40: Matsuda, Araga & Yoshino, 1975, p.192, pl.29, colored fig.B.
Beryx decdactylus [*sic*]: Munro, 1958a, p.78, fig.542.

Remarks

The vernacular name in the Handbook (Munro 1958) (in which the first "a" of the second binomen is inadvertently omitted) is the widely adopted "imperador", the other Australian species of the genus, *B. splendens* Lowe, 1834 being designated the "alfonsin". This reaches English dictionaries as a general name for several berycoid fishes found at Madeira and in the West Indies, and Gunther (1887, p.32) quotes Lowe (1843) as reporting that Madeiran fisherman, engaged in an important fishery involving this family, call the present species the "Alfonsin a casta larga" and *B. splendens* as the "alfonsin a casta cumprida", its body being noticeably the shallower of the two. Australian records note the occurrence of *B. decadactylus* at 330-435 m, while the *Challenger* collected examples off Inoshima in 535 m. Remains attributed to *Beryx* and allied genera have been found abundantly in the Cretaceous.

Tasmanian Record

A specimen, *Ls* 385 *Lt* 511, taken by Mr Shane Down 23 km east of Birnalong Bay, east coast, in 330 m in March 1980 (Q.V.M. Reg. No. 1980/5/34).

Meristic Characters

Counts in parentheses given first are those of the Handbook (Munro 1958, p.78) followed where appropriate by those in Matsuda, Araga & Yoshino (1975). D. IV, 20 (IV, 18-19; IV, 16-20). A. IV, 30 (III-IV, 28-29; III-IV, 27-30). V. I, 10 (I, 10; I, 9-10). P. left 16, right 20 (15-16; 16-18). C. main rays 24. L. lat. 73 (63-71). L. tr. 10/23 (9-10/17-18). Gill rakers on lower anterior arch 19, slender, somewhat flattened, bluntly pointed, decreasing in length ventrally, longest half snout. The higher count in the right pectoral of the present specimen is accounted for by the occurrence of additional small and very small rays at the beginning of the lower border of the fin; clearly an individual peculiarity. The caudal fin is preceded above from the dorsal termination back by a series of spines developed as prolongations of the scales of the superior profile; approaching the fin base these increase notably in length (last four 4, 13, 25, 46 *TLs*), the hindmost virtually becoming an integral element in the overall structure of the fin. On the ventral surface a series of some eight scales without spines is followed by two spines 17, 23 long. Some observations on these pseudospines are made below in the account of *Centroberyx affinis*.

Dimensions as *TLs*

Length to end of upper caudal lone 1296 to end of lower caudal lobe 1372 to end of middle caudal rays 1169. Length to origin termination of dorsal 475 714 of anal 631 909.

Length to origin of pectoral 309 total length of fin 314 length of longest (5th) ray 270. Length to origin of ventral 405 total length of fin 556 length of longest ray (2nd from spine) 250. Length to vent (middle) 517. Head 351. Snout 83. Eye 132. Interorbital 73. Lengths of dorsal spines 14, 19, 109, 110 of first longest (2nd) last rays 244, 260, 87. Lengths of anal spines 10 20 89 99 of first longest (2nd) last rays 184 190 60. Length of ventral spine 149 of adjoining ray 239; for other rays see Aspects of Form, below. Depth (width) at front of eye 213(127) back of eye 379(145) opercular border 447(151) dorsal origin 478(138) vent 468(135) anal origin 431(119); maximum 481(156), caudal peduncle 123(90).

Proportions

The main diagnostic proportions are in good agreement with those given in the Handbook (Munro 1958, p.78) — depth in standard length 2.08 (Handbook 2-2.3) head in standard length 2.85(3) eye in head 2.65(2.5) eye in interorbital 1.86(1.66).

Aspects of Form

Length of head, length to vent, standard length. In a loglog plot these three primary dimensions yield a significantly straight line (t 53.201*) on {1 2 6}:

Log L = 0.5863 log N + 2.5418; calculated (measured) lengths, *TLs*, 348(351) 523(517) 996(1 000).

Location of vertical fin origins and terminations. In a loglog plot {length to dorsal origin anal original dorsal termination anal termination caudal origin} fall collinear with statistical significance (t 45.332***) on {3 5 6 9 10}, the equation of the best straight line being:

Log L = 0.6116 log N + 2.3798; calculated (measured) lengths, *TLs*, 470(475) 641(631), 717(714), 919(909), 981(1 000).

A comparison of the location pattern of vertical fin origins and terminations in this species with those for *Centroberyx affinis* (Günther, 1859) (in which the integral abcissal coordinates are 3 5 7 8 10) and *Paratrachichthys trailli* (Hutton, 1876) (in which they are 2 5 6 7 10) is exhibited in fig. 1.

Anal spines. In a number of diverse species possessing three anal spines a common pattern that has often been noted in these studies has their logarithmic lengths a function of the logarithms of their serial numbers. While in the four other berycids found in Australian waters the spines are regularly IV (regularly so also in the allied polymixids and the still more closely allied holocentrids), the count in the "imperador" may be either III or as in our example IV. In the present fish these constitute two pairs with their lengths falling in a loglog graph on the first two and the last two of the natural-number series 1-10:

Log L = 0.9539 log N + 1.0490; t 19.901**; calculated (measured) lengths, *TLs*, 11(10) 22(24) 91(89) 101(99).

Dorsal spines and rays. In this specimen the four dorsal spines exhibit the same length-number pattern as the four anal spines, being two pairs of markedly different size with their logarithmic lengths collinear when plotted on logs 1 and 2 and logs 9 and 10.

Log L = 0.8810 log N + 1.1752; t 31.888***; calculated (measured) lengths, *TLs*, 15(16) 28(26) 104(106) 114(113).

The dorsal rays show some irregularity in length, increasing to 2nd then decreasing to 11th; 12th ray marginally longer than 11th but lengths then decreasing to 17th, with 17th < 18th < 19th > 20th. The logarithmic lengths of the set of seven rays 5th-11th is significantly linear, t 23.089***, on (as is usual in a descendant series) the logarithms of their reverse serial numbers, *i.e.*, on logs 10-16.

Log L = 1.1923 log N' + 0.8071; calculated (measured) lengths, *TLs*, 100(96) 112(114) 124(125) 137(140) 149(153) 162(161) 175(169).

Ventral. The presence in this family (and in some other Beryciformes) of a number of ventral rays in excess of the very widely found complement of 5 has long been interpreted

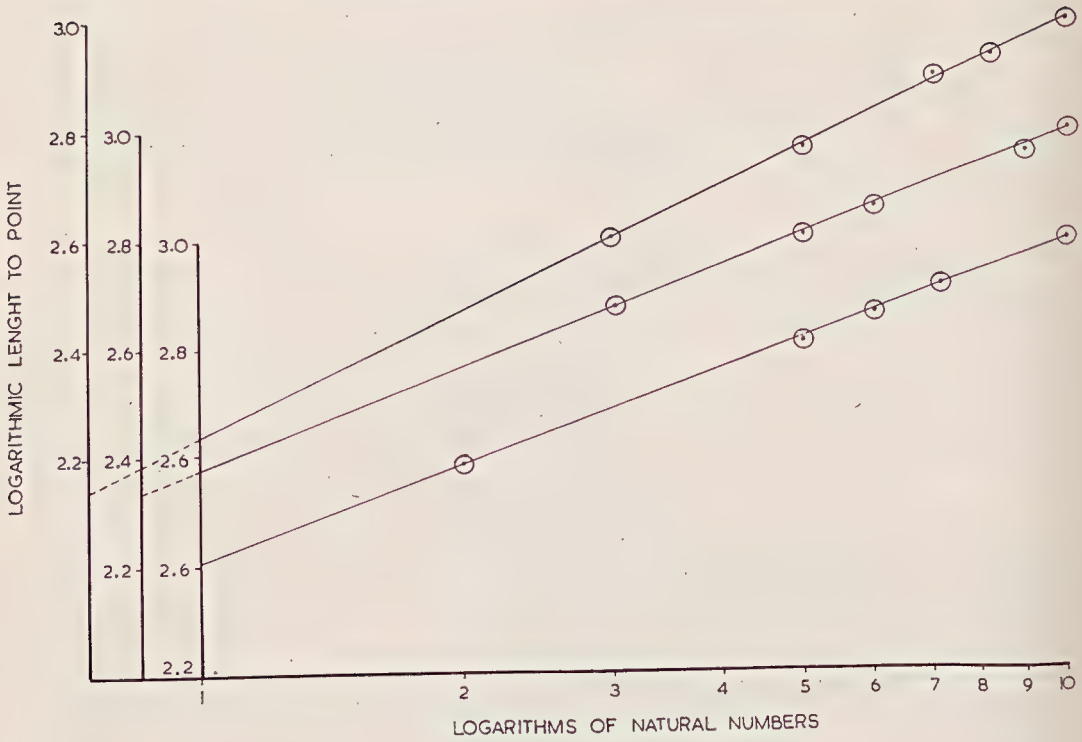

FIG.1 - Location of dorsal origin, anal origin, dorsal termination, anal termination and caudal origin according to the relation $L = b\ N^k$, where L = length to origin or termination (measured as thousandths of standard length) N = a natural number (2-10); illustrating the permutations exhibited by the related species, *Centroberyx affinis* (Günther, 1859), top graph, *Beryx decadactylus* Valenciennes, 1829 and *Paratrachichthys trailli* (Hutton, 1875), bottom graph.

(Boulenger 1910) as the retention of an archaic character. Among Australian Berycidae three species have 7 rays while in *Beryx splendens* Lowe, 1834 the count ranges fron 10 to 13 (such variability in this normally constant fin presumably being indicative of evolutionary instability). In the 10 in the present species the lengths (as found in our example) increase from first ray (defined as that farthest from spine) to ninth, with (as is usual also in 5-rayed fins) the last ray a little shorter than the penultimate, subequal to the antepenultimate. As is modally the case with the set of four successively longer rays, the logarithmic lengths of the nine here are a function of the logarithms of their serial numbers:

Log L = 0.54 log N + 1.8875; t 27.591***; calculated (measured) lengths, *TLs*, 77(82) 112(106), 140(134), 163(158), 184(184), 204(210), 221(226), 237(242), 253(250).

Precaudal pseudospines.. The lengths (4 13 25 46 *TLs*) of the four spine-like processes developed on the dorsal profile immediately in advance of the caudal are related to their serial numbers thus $L = b\ N^k$, the slope of the rectified equation (k) being 1.7369, the intercept (log b) 0.5949: t 75.737***; calculated values of L 4 13 27 44.

General Features

Maxilla to below 0.5 eye, its greatest width 0.42 its length (165 *TLs*). Isthmus to below 0.1 eye. Pectoral to level of 13th dorsal ray, ventral to base of 3rd anal spine. Lower jaw slightly projecting, a median knob fitting into edentulous segment of upper jaw. Oval posterior nostril about one-sixth eye, its distance fron orbit twice its length, one and a half times its distance from posterior nostril, which is about half as large, more rounded. Teeth in upper jaw in right and left narrow bands tapering anteriorly to a point, in oblique rows of up to a dozen, minute pointed, not or barely erect directed inward and backward, a symphysial diastema with arc about one-fifth eye diameter; in lower jaw much as in upper, anterior ends of bands less than half as far apart; on vomer somewhat larger, in a transverse strip with anterior border convex posterior slightly sinuous, 5-6 rows at its middle; on palatine a single row of upwards of two score, larger than in jaws strongly recurved, acute.

Scales extending forward on to occiput in a conspicuous sharply delimited broad pennon reaching nearly to level of front of orbit, its width at back of eyes subequal to sum of widths of flanking scaleless strips there. Naked area of dorsum and whole of preorbital with numerous scattered minute pits with low subcircular rims. Operculum with some irregular scales much less clearly defined than those of flank. A scaly sheath along whose base of anal of virtually even height throughout, 2-3 rows of scales proximally, smaller than adjacent scales, external to these a single row of decidedly larger, less pigmented scales forming a distinct frill-like somewhat crenulated free border; a rather less developed sheath along dorsal base; on caudal a conspicuous median lingulate squamous extension backward from general caudal peduncle to end of median caudal rays.

Coloration

The "imperador" is a handsome species, being bright uniform carmine on the whole of the head and body and all the fins. The inside of the mouth is mostly whitish with some traces of pale pink (contrast the "alfonsin", *Beryx splendens* Lowe, 1834, with inside of mouth bright red).

Genus *CENTROBERYX* Gill, 1862

Beryx Cuvier, 1829, REGN. ANIM., ed.2, p.151. Type-species, *Beryx decadactylus* Cuvier.
Hoplopteryx Agassiz, 1839, POISS. FOSS., 4, p.4. Type-species, *Hoplopteryx denticulatus* Westward. (Spelt Hoplopterix, p.131.)
Centroberyx Gill, 1862, *Proc. Acad. nat. sci. Philad.*, 14, p.238. Type-species, *Beryx lineatus* Cuvier.
Trachichthodes Gilchrist, 1903, *Mar. invest. S. Afr.*, 2, p.203. Type-species, *Trachichthodes spinosus* Gilchrist.
Austroberyx McCulloch, 1911, p.39. Type-species, *Beryx affinis* Günther.

Centroberyx affinis (Günther, 1859)
Fig. 1

Beryx affinis Günther, 1859, p.13. Type locality: Australia (Warwick) [=Sydney?, *fide* McCulloch (1929, p.131)].
Beryx affinis: Castelnau, 1878, p.225: Macleay, 1881, p.525: Johnston, 1883, p.109 and 1891, p.31 *in* Whitley (1929), p.49: Ogilby, 1893, ED. FISH. N.S.W., p.69, pl.21: Stead, 1908, ED. FISH. N.S.W., p.48, pl.17.
Hoplopteryx affinis: Regan, 1911, *Ann. Mag. Nat. Hist.*, 8(7), p.5.
Austroberyx affinis: McCulloch, 1911, p.43, fig.11.
Trachichthodes affinis: Waite & McCulloch, 1915, *Trans. R. Soc. S. Aust.*, p.463: Roughley, 1916, FISH. AUST. AND THEIR TECHN., p.49, color pl.11 and 1951, p.26, color pl.7: Waite, 1921, p.69, fig.105 and 1923, p.94, unnumbered fig.: McCulloch, 1921(a), p.43, pl.27, fig.117a and 1922, FISH. AND FISH-LIKE ANIM. N.S.W., p.33, pl.12, fig.117a and 1929, p.131: Lord, 1923, p.65 and 1927, p.13: Lord & Scott, 1924, pp.9 44, unnumbered outline fig.: Whitley, 1929, p.49: McCulloch & Whitley, 1925, *Mem. Qld Mus.*, 8(2), p.129: Marshall, 1964, p.128, pl.29, fig. 139 and 1966, TROP. FISH GREAT BARR. REEF, p.178, pl.29, fig.139.

Centroberyx affinis: Whitley, 1948, p.16 and 1962, p.71, unnumbered fig. and 1964, p.40 and 1968, p.47: Scott, 1962, p.103, unnumbered fig.: Selickaya, 1971, p.157: Scott, Glover & Southcott, 1974, p.116, unnumbered fig.: Pulley, 1974, MAR. FISH. AUST. WAT., p.65, unnumbered fig. opposite p.89: Thomson, 1974, p.117 and 1977, p.86: Pollard, 1978, p.102 (incidental reference).

Note on Vernacular Name

There has been some continued confusion regarding the vernacular name of this species, early on concerned only with differences in orthography, more recently involving quite different appelations. Oliver (1871) described it as *moora Nennigae*; Macleay (1881) headed his description "the *Nannygai* of Sydney fishermen"; Tenison-Woods (1882) gave reasons why the aboriginal name *mura ngin a gai* had been corrupted to *nan a dai*, this last rendered "Mother *Nan a di*" by Whitley (1962). From the first Australian catalogue of Macleay (1881) onward to the revised South Australian catalogue of Scott, Glover & Southcott (1974) systematic authors in Australia have almost invariably used *nannygai nannagai nannegai nanegai* (Castelnau, 1978) or *nannygy* the first being the preferred form. The Handbook (Munro 1958) provides an exception, giving redfish as an alternative name.

However, a different position has obtained more or less consistently for some two decades in the literature of commercial fisheries. While the first list of uniform names agreed upon at the annual conference of Australian Fisheries officers in February 1947, published as a large single-sheet supplement to the Commonwealth Government's *Fisheries Newsletter* (June 1947) compiled by G.P. Whitley and covering some 40 species does not include the present species, a second list (containing 57 names, some of which were changes in the names agreed upon in 1947) formulated by a similar conference in September 1960 and published shortly afterwards (*Fisheries Newsletter* November 1960, p.71) gave the official vernacular name as redfish. Regarding this change of name Thomson (1974, p.117) observed this fish "is one of the best sellers under the name of redfish which the public accepted as they never did the exotic [*sic*] name of nannygai". *Centroberyx affinis* has since appeared in the Fisheries Division's periodical as redfish in monthly and yearly tables of weights of catches and market prices: special illustrations include a colored cover picture (*Australian Fisheries* February 1971), with text "Redfish or nannygai", and No.37 in a series of 60 paintings by Robert Ingpen (*Australian Fisheries* February 1975, unnumbered centrefold between p.40 and p.41).

Several tangential elements of confusion remain to be noted. The closely allied, morphologically similar *Trachichthodes gerrardi* (Günther, 1887) — figured in color in *Australian Fisheries* (June 1978) — formerly known as red snapper or Bight snapper [Snapper = *Chrysophrys guttulatus* Valenciennes, 1830] is now officially designated Bight redfish, the change being made "in the hope of better selling" (Thomson 1974, p.121). In a comparison of 5 species of Berycidae Thomson (1977, p.86) heads his key, comprehensively, "Redfish". Pollard (1978, p.102) applies the name nannygai to *Trachichthodes lineatus* (Cuvier, 1829), previously widely known as the swallowtail, remarking "not to be confused with *Centroberyx affinis* or redfish". As further, it may be hoped final, complications Marshall (1964, p.128) reports that nannygai is used at the Brisbane Fish Market for *Glaucosoma scapulare* Macleay, 1881 (Glaucosomidae), elsewhere commonly known as pearl fish, pearl perch or epaulette (or epaulette fish), and Roughley (1951, p.27) states nannygai has appeared with this connotation in the official annual reports of the Queensland Fish Board. Again, Grant (1978) dealing also with Queensland usage, lists nannygai, large-mouthed nannygai, small-mouthed nannygai as alternative names for *Lethrinus chrysostomus* Richardson, 1848, *Lutjanus malabraicus* (Bloch & Schneider, 1801), *Lutjanus sanguineus* (Cuvier, 1828), for which the preferred vernaculars are sweetlip or sweetlip-emperor, scarlet sea-perch, saddle-tailed sea perch, respectively.

Commercial Importance

In New South Wales *Centroberyx affinis* is one of the State's most abundant food fishes. Examination of the tables of fish market returns published monthly in the Australian Government *Australian Fisheries*, in which it is listed under redfish, shows

that in 1979, it occupied first place by weight in 6 months second in 5 third in 1, the recorded catches ranging from 68 699 kg to 330 980 kg, mean 154 687 ± 23 465. It is, however, decidedly the cheapest of the fish listed, the price being 29-64 (mean 42.4) cents per kg. It does not appear in either of the lists for Victoria or Queensland, the only other States for which returns are published. Roughley (1951) stated the catch of approximately 45 000 kg of this fish in 1944-5 increased in 1948-9 to 2 500 000 kg or 38% of the total catch of the trawlers and Danish seiners.

It is of interest to note in passing that five other fish found in Tasmanian waters are represented among the three at the top of the tables, namely, gemfish, *Rexea solandri* (Cuvier, 1832) (in Tasmania traditionally kingfish or Tasmanian kingfish, also king barracouta, hake; appearing in local lists also in the genera *Thyrsites* Cuvier, 1832, *Jordanidia* Snyder, 1911): the name hake, inviting confusion with the unrelated European *Merluccius vulgaris* remained in general use till the decision in 1974 of the Standing Committee on Fisheres (*Australian Fisheries* May 1975, p.18) that the fish should henceforth be marketed in New South Wales as gemfish (a name suggested (*Australian Fisheries* September 1974, p.12) by that of the family to which it belongs, Gempylidae) occupying first, second and third position in 3, 3, and 2 months; "flathead, trawled" (unspecified Platycephalidae) in 2, 1 and 3; morwong, *Nemadactylus macropterus* Bloch & Schneider, 1801 0, 2 and 5; sea (bully) mullet, *Mugil cephalus* Linne, 1758 2, 0 and 0; snapper, *Chrysophrys guttulatus* Valenciennes, 1830 (appears in the Check-List (McCulloch 1929) as a synonym of *Labrus auratus* Bloch & Schneider, 1801 referred by McCulloch to *Pagrosomus* Gill, 1893) 0, 0 and 1. Mean prices, cents per kg, quoted in New South Wales in 1979 for these five items were in sequence as above, 43-116 (mean 80.7), 88-143 (109.7), 91-181 (120.9), 42-118 (76.0), 210-400 (307.5). Of these species the deep-water *Centroberys affinis* is, as noted earlier, seldom taken currently in Tasmania; *Chrysophrys guttulatus* also is uncommon; *Mugil cephalus* is abundant particularly on the eastern and northern coasts and is a familiar sight in fish shops; of *Rexea solandri* Johnston (1881, p.25) wrote "Season, December to June. Come and go in vast numbers, but disappear in some years altogether", while Lord & Scott (1924, p.81) observed "At one time these fish were abundant in Tasmanian waters, and constituted one of the chief food fishes, but they are now seldom caught"; currently they make an occasional appearance in the market; several species of platycephalids are among the best known commercial fishes and are also taken in very great numbers by amateur anglers, often by spearing at night.

An important paper on the distribution and general biology of the nannygai is that of Selickaya (1971), based on material from the TNIRO expeditions that carried out research in the Great Australian Bight in 1965-1967. Conclusions arrived at include: *Centroberyx affinis* is found in the Bight regularly between 124°40'E and 134°35'E in waters at 13°-19°, the largest catches in the central part being in 150-175 m, in the western part in 170-200 m; though a large number of trawlings were carried out, no fish were obtained outside the range 64-225 m; a substantial upward migration occurs in March-April, the latter month being the climax of the breeding season (February-March); the sex ratio is close to 1:1; the chief food is euphausians, with supplementation from prawns, crabs, fish.

Regarding the occurrence of this species in Tasmania, Johnston (1883) noted "Rare" and Lord & Scott (1924) observed "not often taken in Tasmania. Trawling operations would doubtless secure many of this species, for they are occasionally taken off the coast. Mr. W. Beddome secured a number a few years ago when fishing from his yacht near the entrance to D'Entracasteaux Channel". Two entries in Johnston's memoranda, redacted by Whitley (1929) show the interest with which local occurrences were regarded by the doyen of Tasmanian ichthyology. "A fine specimen" caught in the Derwent in 1895 — "Examined by me and found to be in all characters identical with those caught more abundantly near Sydney". The second may be quoted verbatim from Whitley. "[Note added much later, in shaky handwriting:-] 4 specimens in Fish Shop, Elizabeth [Street, Hobart]. Caught in Derwent Estuary, 14th March, 1918. One of the specimens about 15 inches [38 cm] long. Evidently this is the season when the "Nannegai" *Beryx affinis* enters the estuary of the Derwent. R.M.J."

Observations on some Tasmanian Fishes: Part XXVII.

Material

The primary data here reported has been provided by an example, (a), *Ls* 231 *Lt* 313, taken by Miss P. Bennell at St Helens (Q.V.M. Reg. No. 1958/5/26). Observations on this Tasmanian fish have been supplemented by an examination of six smaller Victorian specimens (b)-(g) made available through the courtesy of Dr Martin F. Gomon, Curator of Fishes, National Museum of Victoria, Melbourne - (b) (c), *Ls* 117,111 *Lt* 161,155, Victoria, 16 km south of Lakes Entrance, taken with Danish seine by the *Tambo Bay*, November 1973, Acc. No. 79.1; (d) (e) (f) (g), *Ls* 101.5,101,90,89.5 *Lt* 144,139,125,123.5, Victoria, off Phillip Island, 38°32'S 145°15'E, collected by W. Mitchell and T. Montague, 7 August 1979, Reg. No. A630.

Meristic Characters

Figures in parentheses denote number of instances. D. VII, 11(1) 12(5) 13(1). A. IV, 12(5) 13(2). V. 7. P. 1, 12(13) 13(1, left fin). C. 19(6) 18(1) (modally, upper and lower moieties each with 9 rays and an azygous median ray), preceded above and below by 5 pseudospines (see below). L. lat. 41(1), 43(3), 44(2), 45(1). L. tr. 6/11-13. Gill rakers on anterior arch 9-11 + 19-21, slender elongate more or less rodlike but slightly compressed, delicately spinulose along two edges, increasing from above and from below to angle of arch where they are subequal in length to longest gill filaments.

Dimensions

Dimensions of the seven specimens are set out in table 2, all entries being millesimals of standard length, except those of the first line which record standard length in millimetres.

Proportions

The principal diagnostic proportions of the adult example are followed by the range and the mean with standard error of the six juveniles; values in parentheses are those of the Handbook (Munro 1958a, p.78). Depth in standard length 2.22; 2.02-2.29; 2.11 ± 0.47, in total length 2.84; 2.81-3.19; 2.93 ± 0.07 (2.6-3.3). Depth of caudal peduncle in head 3.11; 2.09-3.07; 2.90 ± 0.07. Head in standard length 2.75; 2.59-2.73; 2.65 ± 0.02, in total length 3.51; 3.63-3.76; 3.69 ± 0.02 (3.4-3.5). Snout in head 3.50; 3.70-4.67; 4.01 ± 0.15, in eye 1.13; 1.19-1.70; 1.35 ± 0.09 (1.20). Eye in head 3.11; 2.73-3.22; 2.99 ± 0.09 (3). Interorbital in eye 1.21; 0.98-1.18; 1.06 ± 0.002. Pectoral in head 1.23; 1.05-1.21; 1.13 ± 0.03, in standard length 3.39; 2.78-3.19; 3.01 ± 0.08. Ventral in head 1.67; 1.40-1.51; 1.47 ± 0.03, in standard length 1.72; 1.71-1.78; 1.73 ± 0.01. Dorsal base in standard length 2.64; 2.69-2.96; 2.79 ± 0.05. Anal base in standard length 3.91; 3.64-4.14; 3.96 ± 0.09. Within the (narrow) length range of the juvenile set (though not with the inclusion of the adult) relative depth exhibits significant positive correlation with standard length (r 0.972 z 1.770 t 11.158***) or with total length (r 0.916 z 1.564 t 4.571**). No other clear correlations are apparent in the small sample.

General Features

The following account is based in the first instance on the adult Tasmanian specimen, variations exhibited by the Victorian juveniles receiving separate notice. Maxilla to just beyond hind margin of eye (in (b) (c) to hind margin, (d) (f) to 0.9 eye, (e) (g) to 0.8 eye); Handbook "to below hind half of eye": its greatest width 0.43 (0.40-0.45 $\bar{x}$ 0.427 ± 0.007) its length, which is 203 *TLs* (188-207 $\bar{x}$ 197.5 ± 2.59). It is largely overlapped by a rugose supplemental bone covering half or more of the width of most of the shaft and occupying the upper one-third or so of the expanded distal end, its linear (in young delicately denticulate) border here surmounting a broad subtriangular smooth maxillary component of the jaw. Isthmus to below anterior margin of orbit, its squamous part about to level of middle of eye. Dorsal originating over pectoral base, ending above 7th (7th-9th) anal ray, anal originating below 3rd (1st-3rd modally 1st) dorsal ray, pectoral extending to level of 5th (2nd-5th) dorsal ray, ventral extending to base of 1st (1st-3rd) anal spine. Upper lobe of caudal noticeably the longer (in (f) lobes subequal); emargination marked, the difference between length to tip of upper caudal lobe and length to end of middle caudal rays 229 (159-263 $\bar{x}$ 197.3 ± 17.33) *TLs*, the excess in the juvenile sample showing negative correlation with standard length (r −0.854 z −1.274 t 3.289*).

TABLE 2

Centroberyx affinis (Günther, 1859)

Dimensions of (a) an adult Tasmanian example, (b)-(g) six Victorian juveniles. Entries in the first line, standard length, in millimetres, all other entries as millesimals of standard length.

Dimensions	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Standard length	231	117	111	101.5	101	90	89.5
Length to end of upper, lower caudal lobe	1355,1277	1385,1359	1396,1369	1419,1404	1378,1356	1389,1390	1380,1335
Length to end of middle caudal rays	1126	1226	1252	1222	1163	1183	1117
Length to origin, termination of first dorsal	411,597	444,582	424,532	426,544	446,603	449,607	426,547
Length to origin, termination of second dorsal	602,790	591,787	554,793	555,798	605,810	622,794	547,663
Length to origin, termination of anal	584,840	600,862	604,847	608,858	620,861	598,839	573,821
Length to pectoral, total length of fin	346,295	308,342	347,368	338,320	347,342	361,319	358,314
Length to longest pectoral ray	273	282	363	307	266(5th)	311(6th)	286(6th)
Length to ventral, total length of fin	411,217	376,249	396,260	394,271	416,262	389,261	374,246
Head	364	396	378	384	366	380	380
Snout	104	94	81	99	99	94	101
Eye, interorbital	117,97	138,120	138,117	119,122	118,115	124,134	123,123
Length to vent	580	583	586	578	575	581	561
Lengths of dorsal spines	45,78,100,128, 144,168,178	60,92,111,145, 158,179,192	47,80,109,135, 161,171,199	48,84,117,138, 163,177,206	49,80,113,139, 163,189,-	66,99,126,154, 178,201,224	56,89,123,147, 173,189,212
Lengths of anal spines	19,51,91,139	38,77,117,154	27,64,116,171	41,86,123,176	37,78,113,145	44,87,122,146	34,73,121,156
Lengths of superior pseudo-spines	19,39,61,87,113	16,41,64,94,120	18,44,72,99,122	29,49,70,89,117	30,50,69,94,107	28,54,72,100,123	17,39,64,89,118
Lengths of inferior pseudo-spines	16,35,52,78,103	17,38,61,92,114	18,41,62,91,105	30,48,79,97,118	18,41,64,89,107	22,44,73,103,128	21,45,65,89,112
Lengths of first, last, longest dorsal rays	130,95,215	295,113,295	241,135,241	259,128,259	231,117,231	259,102,259	235,108,235
Lengths of first, last longest anal rays	113,78,173	164,90,164	167,109,180	182,111,182	178,119,187	156,79,187	179,95,190
Lengths of ventral rays; spine	108,139,156,177, 195,203,199;169	144,166,178,188, 196,205,190;159	135,171,196,216, 221,234,207;163	139,167,192,216, 231,244,224;177	131,156,171,188, 197,203,198;168	122,159,180,200, 222,233,221;178	147,169,171,191, 200,203,201;162
Depth before eye, behind eye	260,398	265,393	234,396	271,394	307,406	294,411	268,391
Depth at opercular border, at vent	450,424	430,410	464,459	473,468	490,485	489,478	480,464
Maximum depth	450	436	464	478	490	494	492
Depth at caudal peduncle	126	124	135	125	137	133	128

Lower jaw projecting, with a broad medial process, its frontal aspect in the form of a truncated triangle (less conspicuous, more rounded in juveniles), each side with a row of 6-7 teeth, the innermost largest (in some juveniles subequal); a cluster of obscure odontoid processes on external surface at the base on either side (barely or not developed in juveniles); the whole fitting into an edentulous notch in upper jaw. Posterior nostril elliptical, its major (vertical) axis about one-sixth eye, its distance from orbit subequal to its length and to distance between its anterior border and anterior border of the posterior nostril, the latter somewhat smaller, more nearly round; both with a raised rim, that of the posterior wider, somewhat more elevated: internarial about two-thirds eye. Teeth in the upper jaw in a narrow transversely rounded band, minute, tuberculate, except for a small space anteriorly, rather less than an eye diameter, where there are a few (left side 5, right 10) larger blunt peglike teeth (rather less clearly differentiated in juveniles); behind the medial process in the lower jaw teeth larger than in upper jaw, though still small, mostly biserial in parts triserial; on vomer small, blunt in a small patch, subtriangular, apex anterior (or with the sides of the triangle produced briefly back behind the base); on each palatine in a band similar to that in one side of the upper jaw.

Scales strongly ctenoid, modally with about three dozen long slender spines projecting beyond exposed margin, usually near middle, extending forwards as conspicuous parallel ridges. Covering trunk and tail, extending as a weak sheath of one or two rows on to dorsal and anal bases, forming two contiguous patches on caudal base, small and obsolescent on pectoral base: on head ceasing abruptly on dorsum above anterior one-third (middle or posterior one-third) of eye and on side above four smoothish minutely papillate areas (in juveniles three, the soft uppermost not clearly recognizable) surmounting the opercular system; covering most of operculum; on preoperculum narrowly and imperfectly fringing vertical limb, broadening to a subtriangular patch at the angle; remainder of head scaleless. Several specialized areas on head, smooth, usually minutely papillate, sharply delimited, usually by ridges, which may be denticulate. The principal such areas are: a median lanceolate region on the interorbital dorsum extending from level of anterior nostril to that of pupil; flanking this on either side a strip of slightly greater maximum width curving back beyond the eye to bound the preoperculum, the paired strips terminating anteriorly, virtually in contact, along the hind margin of a subrectangular patch of skin, the latter bordered laterally and except for a small median hiatus also in front by an anterior extension of the preorbital, the short curved anterior margin of which carries an arc of 8-10 spines; a largely smooth minutely papillate broad arc below eye, reaching back almost to vertical limb of preoperculum, the first one-third of its inferior border with a score of small spines, the middle one-third entire, the hind one-third with some two dozen somewhat larger spines directed down and back; above the large supraorbital arc a lanceolate strip starting at level of front of pupil and reaching to level of posterior orbital border; some distance behind this at about the same horizontal level a smaller curved pennon; the space between these two filled with a smooth patch that expands above them to be in contact with the hind half of the first. Chin back to level of middle of eye with irregular striae, some feebly spinigerous; in (a) numerous small circular or ovoid openings between them. Hind half of orbit with three largish two-winged ridged and spined processes; a fourth above these usually developed in juveniles. Preoperculum with two subvertical borders, both denticulate, both with larger spines forming a conspicuous group at the angle; operculum with throughout most of its length parallel ridges ending in spines, two prominent spines about at level of middle of eye, the upper the larger, subequal to pupil; interoperculum minutely ridged and crenulate. All fin rays stout, more or less flattened distally, divided to or virtually to base, secondary fission occurring near middle of length, ray terminating in up to 8, exceptionally more, rami.

The Handbook (Munro 1958a, p.78) states "No keeled abdominal scutes": apart from recording the l. lat. count (43) and l. tr. (6/12), the account of this species by Castelnau (1878) makes no reference to scales. Here 11 median scales between the ventral base (where the foremost is partly overlapped by two or three normal scales) and shortly in advance of the vent differ trenchantly from other scales along the lower edge of the

fish (and elsewhere), taking the form of two large plates (triangular at either and of the series elsewhere more or less clearly pentagonal) sloping towards each other to meet in the midventral line where they develop a low but distinct carina. In the adult this ridge does not bear prominent spines; however, a small prone pointed process, readily detectable by touch, occurs on it at the hind border of each scute, being quasi-continuous on each side with the uppermost of a series of low subparallel longitudinal striae that (except in the first two scutes where they are absent and in the next two or three where they are little developed) cover most of the modified scale. In specimens (b)-(g), juveniles, in which the specialized scales range in number from 9 to 12, distinct strong spines are developed, most notably in the anterior part of the series, where they may be little inferior in size to the first anal spine. There would appear to be no essential difference between these structures and those in *Paratrachichthys trailli* recognized in the Handbook as abdominal scutes.

Rays obviously identifiable as normal caudal rays are preceded on both the dorsal and ventral profiles by 5 interesting structures recorded in the meristic specifications above as pseudospines. In so far as their location is concerned, these of course correspond to the procurrent rays found in a wide range of species of many families: their nature and mode of development would appear to be such as to place them in a special class. They exhibit characters of both body scales and fin rays, being suggestive of the development of the latter from the former. The most anterior one, inserted somewhat in advance of the hypural joint, is foliate, compressed fore and aft, subtriangular in frontal view, its base wide about one-third its length, the anterior surface strongly transversely convex, the posterior surface attached by integument to the next pseudospine for about the proximal five-sixths of its height, the acute free end slightly concave: this structure is clearly a modified scale, being immediately preceded by normal scales differing notably from it only in having the free posterior margin in the form of a broad spinigerous arc instead of a wide pennon with a single acute point. Succeeding pseudospines progressively lengthen not only absolutely but also relatively, the length of the last exceeding its basal width by a factor of about 10, the general form closely approximating that of a normal ray. The structure is decidedly spine-like in respect of its shape (in other than the first one or two members of the series), its largely (particularly distally) translucent vitreous appearance (in marked contrast to the opaque true rays, pale gold in the preserved specimen) and its very considerable rigidity. Its ray-like nature is evidenced by the progressive development, readily visible under a lens, of septa: in the first element the beginning of this process is indicated only by the presence of a basal core of undifferentiated opaque yellow; increasing differentiation leads to the formation in the last element throughout the greater part of its length of septa comparable with those of the true caudal rays. The segmentation is more extensive longitudinally in the last ventral than in the last dorsal ray, reaching virtually to the tip; however, the process is more advanced in the dorsal element in respect of the transverse extent of the septa which here extend across the full width, whereas in the anal element a narrow longitudinal strip remains uncolonized. Similar caudal pseudospines occur in *Paratrachichthys trailli* and *Beryx decadactylus*.

Aspects of Form

Head, length to vent, standard length. In a loglog plot of the adult specimen (a) these three dimensions are significantly linear (t 28.054*) on 1 2 5 (*cf.* 1 2 6 for *Beryx decadactylus* and the quite exceptional 10 9 1 for *Paratrachichthys trailli*).

Log L = 0.6268 log N + 2.5659; calculated (measured) lengths, *TLs*, 368(364) 578(580) 1 009(1 000).

Parameters for juveniles (b)-(g): slope 0.5757, 0.7010, 0.5944, 0.6229, 0.6007, 0.6029, intercept 2.5960, 2.5708, 2.5841, 2.5670, 2.5881, 2.5752, t 62.587*, 17.100*, 269.088**, 48.771*, 104.021*, 98.134*.

Location of vertical fin origins and terminations. In a loglog plot {length of dorsal origin, to anal origin, to (second) dorsal termination, to anal termination, to caudal origin} fall collinear with statistical significance (t 138.885***) on {3 5 7 8 10}, the best straight line being:

Log L = 0.7459 log N + 2.2554; calculated (measured) lengths, *TLs*, 408(411) 598(584) 768(790) 848(840) 1 000(1 000).
Parameters for juveniles: slope 0.6845, 1.7121, 0.7121, 0.7169, 0.6791, 0.6700 0.7136, intercept 2.3135, 2.2895, 2.2871, 2.3240, 2.3246, 2.2801, t 29.571***, 54.823***, 45.948***, 37.115***, 21.556***, 18.2358***.
Some discussion of vertical fin location will be found in the observations on *Paratrachichthys trailli* below. The graph for (a) is shown in fig.1.

Dorsal anal and pectoral rays. The length-sequence pattern of the rays in these three fins exhibits one pronounced difference and several remarkable similarities. The pectoral differs from the two vertical fins in having two distal borders conveniently recognizable as distinct, a short leading (upper) edge of 3 rays (smallest inconspicuous) increasing in length from the uppermost — by the convention here adopted, 1st; see Part XIV (1974a, p.248) — followed by a long trailing edge of 11 rays, whereas in the dorsal and anal the border takes for form of a single edge, the rays decreasing in length from 1st, most anterior. The combination of an ascendant and a (usually longer) descendant segment is all but universal in the pectoral, and is more usual in the soft dorsal and in the rayed (main) section of the anal than the single descendant border found here. Secondly, while the slopes of corresponding subsets differ in the three fins, inspection of what may be interpreted as in some way a measure of the energy involved in ray formation, the area under the graph, shows the area per panel (*i.e.*, the interval between successive rays) is significantly the same in each of the fins for each of the subsets. So far as the writer is aware, such a relationship between the three fins has not previously been reported; and while effective equality in the dorsal and anal might not be wholly unexpected, the inclusion of the pectoral, in respect of its trailing (main) edge is certainly interesting and curious.

Data for the rays of the dorsal anal and pectoral are set out in the first 10 lines of table 3, the information provided comprising for each subset the serial numbers of the rays with an indication of whether they are counted directly (N) or inversely (N'), the relevant abscissal integers, parameters and significance of the best straight line for the rectified equation log L = k log N' + log b together with calculated and measured ray lengths, as *TLs* (member common to intersecting subsets included in both for calculation of the subset equations), total area under graph (using measured, not calculated lengths), area per panel. For lines 11-14 of table 3 see below.

Ventral rays. In earlier observations in this series it has in general been found that in fish with the modal ventral formula, I, 5, the lengths of rays 1-4 — first specified as postaxial, see Part XIX (1974b) — are linear in a loglog context on their serial numbers, with spine and ray adjacent to it, 5th, outside the series, this ray shorter than 4th (commonly subequal to 3rd). Here with V. I, 7 the overall pattern is maintained in as much as the spine and its adjoining ray are again outside the exponential length-number set, which in this case comprises 6 instead of the usual 4 rays. The relevant data for specimen (a) are set out in full in table 2.
Parameters for juveniles (b)-(g): slope 0.2505, 0.3077, 0.3212, 0.2506, 0.3641, 0.1835, intercept 2.1175, 2.1377, 2.1362, 2.1175, 2.0854, 2.1695, t 36.065***, 21.922***, 30.493***, 37.695***, 49.887***, 31.443***.

Precaudal Pseudospines

While in some individuals the 5th (hindmost) process is more or less obviously classifiable as a spine, in others it is distincly septate and on the whole more ray-like than spine-like. However, in respect of magnitude it clearly remains a member of the set, being specified by the $L = b\ N^k$ relation exhibited by the others; equally clearly the next element, extending to the distal border of the fin is foreign (in a typical specimen the ratios of the length of each item to the length of the following item are for the set of 5 successively 2.3,1.6,1.4,1.3, whereas for the 5th element and the obvious ray the ratio becones 3.1). All 5 items are here regularly included in the calculation of the rectified equation, data relevant to which in the case of (a) are exhibited in table 2. Parameters for superior series in juveniles (b)-(g): slope 1.2404,1.1976,0.8593,0.8133,0.9120,1.2114,

TABLE 3

Centroberyx affinis (Günther, 1859)

Lengths of spines, rays and pseudospines as a function of their serial numbers, the relation being $L = b\ N^k$ rectified as $\text{Log}\ L = k\ \text{log}\ N + \text{log}\ b$; for reverse serial numbers (counted cephalad) N' is substituted for N: all dimensions as millesimals of standard length. Data for specimen (a), 231 mm in standard length, from St Helens, east coast, Tasmania.

Radial element	Counting sense	Serial numbers	Abcissal integers	k (slope)	log N (intercept)	t	Calculated (measured) lengths, millesimals of standard length	Area under graph Total	Per panel
Dorsal rays	N'	{12-10}	{1-3}	0.1174	1.9795	14.923*	95(95) 101(104) 109(108)	0.9573	0.4786
	N'	{10-7}	{3-6}	0.2523	1.9123	9.519**	108(108) 116(116) 123(121) 128(130)	0.6243	0.2081
	N'	{7-1}	{6-12}	0.7450	1.5340	49.987***	130(130) 146(147) 161(168) 176(174) 190(190) 204(207) 216(215)	0.6692	0.1115
Anal rays	N'	{12-10}	{1-3}	0.2124	1.8924	26.636*	78(78) 90(91) 99(98)	0.9266	0.4633
	N'	{10-7}	{3-6}	0.2060	1.8919	13.907**	98(98) 104(103) 109(108) 113(113)	0.6126	0.3041
	N'	{7-1}	{6-12}	0.6047	1.5912	22.929***	115(113) 127(128) 137(139) 147(145) 157(159) 166(167) 175(173)	0.6463	0.1077
Pectoral rays	N'	{14-12}	{1-3}	0.2793	1.9816	36.553*	98(96) 116(117) 130(130)	0.9767	0.4888
	N'	{12-9}	{3-6}	0.4794	1.8845	36.644***	130(130) 149(149) 165(165) 181(182)	0.6582	0.2194
	N'	{9-4}	{6-11}	0.6421	1.7616	21.781***	183(182) 201(199) 220(222) 237(238) 253(255) 269(265)	0.6164	0.1213
	N	{1-3}	{1-3}	1.9253	1.4743	35.569*	247(248) 113(113) 30(30)	0.9232	0.4516
Dorsal spines	N	{1-7}	{1-7}	0.7019	1.6679	44.684***	45(45) 76(78) 101(100) 123(128) 144(144) 164(168) 182(178)	1.6592	0.2765
Anal spines	N	{1-4}	{1-4}	1.4131	1.2859	98.277***	19(19) 51(51) 91(91) 139(139)	1.0329	0.3444
Ventral rays 1-6	N	{1-6}	{1-6}	0.3536	2.0322	40.820**	108(108) 138(139) 159(156) 176(177) 190(199) 203(203)	1.6886	0.3377
Ventral spine, ray 7	N	{7-8}	{1-2}	0.2381	2.2274	—	—(169) —(199)	0.6814	0.6814
Superior pseudospines	N	{1-5}	{1-5}	1.1356	0.2839	20.062***	17(17) 37(32) 58(53) 82(81) 105(113)	1.1356	0.2839
Inferior pseudospines	N	{1-5}	{1-5}	1.1285	0.2821	29.549***	16(16) 35(35) 56(52) 77(78) 99(103)	1.1285	0.2821

intercept 1.2205,1.2699,1.4446,1.4639,1.4474,1.2253, t 47.521***,33.162***,79.301***, 27.381***,32.348***,257.059***; inferior series: slope 1.1902,1.1182,0.8725,1.1277, 1.0967,1.0274, intercept 1.2294,1.2628,1.4624,1.2605,2.3443,1.3304, t 45.642***,32.068***, 26.754***,39.134***,84.549***,87.575***. The mean interspinous area under the graph (per panel) for the superior series is 0.27-0.31 $\bar{x}$ 0.29 ± 0.018 for the inferior series 0.29-0.31 $\bar{x}$ 0.29 ± 0.01 - significantly the same as for the much larger Tasmanian example (table 2).

Coloration

The appearance in life is concisely described by Castelnau (1878, p.225): "The general colour is of a most beautiful pink, with silver stripes on the body, the edges of the opercules of the last colour". Our adult example, after preservation in formalin, is almost wholly of a uniform dark straw, with some yellow on the head and on some fin rays, otherwise more or less whitish. The Victorian juveniles, in alcohol, in general have the body fawn above the silver lateral line, silvery below it; a narrow stripe of somewhat reddish brown along dorsal profile from just in advance of to just beyond dorsal base, widest near its middle, sharply defined below; whole of hind half or so of caudal peduncle fawn; narrow yellowish strip along anal base; head mostly fawn, more or less silvery below and behind eye and on preoperculum, operculum silvery or golden or partly both; fins pale yellowish to whitish.

Family TRACHICHTHYDAE

Of the seven species listed in the Handbook (Munro 1958a) only two are found in Tasmania, the "sandpaper fish" (occasionally referred to as "roughy"), *Paratrachichthys trailli* (Hutton, 1875), known from all Australian States other than Queensland (and with New Zealand as type locality) and the "roughy" *Trachichthys australis* (Shaw & Nodder, 1799), reported from all Australian States. Only the former occurs in the catalogues of Johnston (1883, 1891) where it appears as the synonymic *Trachichthys macleayi* Johnston 1881 (type locality: Derwent River, Tasmania), being referred to the Berycidae. The latter species was first included in a local list by Lord (1923), where, as in his later list (1927) and in Lord & Scott (1924), it is associated in the Trachichthydae with the former species and with *Centroberyx affinis*, cited in the genus *Trachichthodes* Gilchrist, 1903, this species now being customarily relegated to the Berycidae.

The two species occurring in our waters seldom come under notice locally. In the course of a good account of the only (Victorian) specimen of *Trachichthys australis* that had come under his notice McCoy (1886) gave a table of measurements. No such morphometric data on an Australian specimen of *Paratrachichthys trailli* appear to be available: metrical and other observations on two Tasmanian examples in the collections of the Queen Victoria Museum Launceston are made below.

KEY TO TRACHICHTHYDAE RECORDED FROM TASMANIA

Vent located normally, shortly in advance of anal base.
Head and trunk together subcircular, maximum depth ⩽ 2 in standard length. D. III-IV, 11-12. L. lat. < 80 (*ca* 65).
Reddish brown; a dark bar on operculum .....*Trachichthys australis*

Vent located exceptionally, far forward between ventrals.
Head and trunk together ovate, maximum depth ⩾ 2 in standard length. D. V, 13. L. lat. > 80 (*ca* 118).
Reddish purple; no dark bar on operculum .....*Paratrachichthys trailli*

E.O.G. Scott

Genus *PARATRACHICHTHYS* Waite, 1899

Paratrachichthys Waite, 1899, p.64. Type-species, *Trachichthys trailli* Hutton.

Paratrachichthys trailli (Hutton, 1875)
(Fig. 1)

Trachichthys trailli Hutton, 1875, *Ann. Mag. Nat. Hist.*, 4(16), p.315 and 1876, *Trans. N.Z. Inst.*, (1875), 8, p.212. Type locality: Stewart Island.
Trachichthys trailli: Arthur, 1885, p.162, pl.14, fig.2: Günther, 1887, p.23, pl.55, fig.A.
Trachichthys macleayi Johnston, 1881, pp.11,56. Type locality: mouth of the estuary of the Derwent.
Trachichthys macleayi Johnston, 1883, p.109 and 1891, p.31.
Paratrachichthys trailli: Waite, 1899, p.65: McCulloch, 1911, p.44 and 1921a, p.43, pl.27, fig.120a and 1929, p.132: Lord, 1923, p.65 and 1927, p.13: Lord & Scott, 1924, pp.9,45: Phillipps, 1927, p.24: Munro, 1958a, p.80, fig.552: Whitley, 1968, p.73.
Paratrachichthys trailii Whitley, 1964, p.40.

Date and Name of Species

The species is commonly taken to have been established in Hutton's paper in the *Transactions* of the New Zealand Institute for the session of 1875, published in May 1876, (McCulloch 1929, Munro 1958a, Lord & Scott 1924, McCulloch 1921a, Scott *et al.* 1974). However, Whitley (1964) gave 1875, and in his New Zealand catalogue (1968) cited the earlier account by Hutton in the *Annals and Magazine of Natural History* issued in September of that year (Günther 1887). Whitley (1964) gave the second binomen as *traillii*, but in 1968 accepted *trailli*.

Status of Johnston's Species

In establishing his *Trachichthys macleayi*, based on a specimen 240 mm in total length and having "length of body" (presumably standard length) 190 mm obtained in the Derwent estuary in 1880, Johnston was clearly unaware of the description by Hutton some five years earlier of the New Zealand *T. trailli*. In the first direct comparison of the two accounts Waite (1899), while reporting 13 abdominal scutes as in Johnston as against 11 noted by Hutton (1875) and Arthur (1885) and repeated by Günther (1887), nevertheless accepted *T. trailli*, formally placing *T. macleayi* in synonymy: the question of scute number was later clearly resolved by the finding by McCulloch (1911) in the 17 *Endeavour* examples from Bass Strait and Oyster Bay, Tasmania, of a range of 12-16. In the same paper Waite proposed his genus *Paratrachithys* on a feature Günther (1887) had been inclined to regard as a mere individual abnormality, namely, the location of the vent in front of, instead of behind, the abdominal scutes. The synonymization of Johnston's species has been generally accepted and is probably valid — it may be observed, however, that our material shows no evidence of the lateral line scales being enlarged and "armed with one or two visibly prominent transparent spines", and, as noted below in the section on Proportions, ratios derived from the recorded dimensions of the early fish include several curious values.

Material

Two Tasmanian examples, (a) *Ls* 135 *Lt* 168.5, 6.4 km north of Eddystone Point, taken in 26 m by Mr S. Down (Q.V.M. Reg. No. 1980/5/44), (b) *Ls* 168 *Lt* 211, Tinderbox, collected by Mr P.R. Last (Q.V.M. Reg. No. 1975/5/147).

Meristic Features

D. V, 13. A. III, 10. P. 13/13 13(1eft)/12 (Handbook (Munro 1958a) 12). V. I, 6. L. lat. *ca* 110 120 (Handbook 118, Waite (1899) 118); pierced scales *ca* 50 (Waite 55, Johnston (1881) "about fifty"). Abdominal scutes, 13,15 (Handbook 11-16). Caudal with 19 main rays; 7,8 precaudal pseudospines on dorsal border and 7,8 on anal border (see below, Aspects of Form). Gill rakers on anterior arch 14 + 12, increasing in length from either end to near the middle of the lower limb where they are elongate, flattened,

very slowly tapering, minutely denticulate along either border, subequal to gill filaments Br. 8, the first 2 small and poorly developed, the rest stout, flattened, strongly recurved, the anterior half or so of the inferior border minutely spined, most conspicuously in the 3rd-5th rays.

Dimensions as *TLs*

The dimensions below are given as millesimals of standard length, smaller individual (a) cited first: where measurements of Johnston's type of his *Trachichthys macleayi* (some reported in inches, to the nearest one-eight, some in millimetres) are available values calculated from them are here shown in parentheses. Length to end of upper caudal lobe 1256,1244(1267), to end of lower caudal lobe 1238,1233, to end of middle caudal rays 1125,1111. Length to origin of first dorsal 384,400 to termination 497,522, to origin of second dorsal 506,533 to termination 719,741, to origin of anal 649,649 to termination 804,800. Length to origin of pectoral 321,314 total length of fin 202,204 length of longest (7th 6th) ray 179,178. Length to origin of ventral 351,363 total length of fin, 173,196; for spine and rays see below, Aspects of Form. Length of first dorsal spine – 49(79) of last – 95(89); for other spines see below. Length of first dorsal ray 107,167 (157) of longest (4th 4th) 190,178 of last 95,107(79). Length of first anal spine 16,17 (10) of second 45,47 (31) of third 105,108 (100). Length of first anal ray 168,141(79) of longest (1st 2nd) 168,150 of last 107,81(115): Length of longest precaudal pseudospine 81,85(58). Head 345,333(467). Snout with rostral spines 65,59 without spines 54,52. Eye 101,96(110). Interorbital 110,115. Length of mouth (oblique) 193,202. Length of series of abdominal scutes 237,235(157). Breadth of largest scute 64,54(37) depth 44,42 (37). Depth at front of eye 196,259, back of eye 315,356, opercular border 381,393, vent 390(396), dorsal termination 230,259, anal termination 167,174; maximum depth 390,415 (550), depth of caudal peduncle 117,126(117).

Proportions

Depth in standard length 2.56,2.41 (Munro 2.25-2.5; Johnston 1.82, but depth in total length 2.25; Günther "twice and one-third"). Head in standard length 2.90,3.0 (M. 3-3.2; J. 2.1). Depth of caudal peduncle in head 2.6,2.9 (J. 4.0). Eye in head 3.5, 2.9 (M. 3; J. 4.2; G. three). Eye in interorbital 1.19,1.09. Pectoral in head 1.6,1.7. Ventral in head 1.8,1.7. Longest dorsal spine in head 3.7,3.6 (J. 3.5). Length to vent in standard length 2.80,2.81.

General Features

Where two entries occur the first relates to the smaller specimen (a). Maxilla to below hind border of pupil, to behind orbit by about one-eighth eye, its greatest diameter subequal to direct distance from its posterosuperior angle to orbit. A supplemental bone, widening in its hind half to constitute the greater part of the free end of the jaw surmounting the premaxilla, here very slender. Isthmus to below front half of eye. Dorsal originating over first one-fourth of ventral just behind posteroinferior angle of pectoral base, terminating above 4th anal ray; anal originating below 9th dorsal ray; pectoral to below 2nd dorsal ray, slightly beyond ventral tip, which is just more than halfway to anal. Jaws equal, lower projecting slightly, its tip enlarged, turned up, fitting into a shallow notch in upper jaw, its mesial anterior aspect occupied by a subvertical cutaneous strip bordered below by several small tuberosities. The whole external lower border of the upper jaw constituted by the premaxilla in the form of a narrow band continuing to narrow markedly and (save for a brief notch on the upper border about as wide as its distance from the anterior end) evenly backward; the entire surface closely beset with minute pointed elevations that appear along the inferior as downwardly pointed teeth; a short edentulous interval at symphysis. Lower jaw much the same but band in general decidedly narrower though expanding near symphysis to a width slightly exceeding maximum in upper jaw. A very small triangular patch of about a score of minute teeth on the middle of the vomer. A slender minutely dentigerous band on each palatine, similar to, but narrower than, and about half the length of, that of the upper jaw. Tongue absent in (a), in (b) stout, its tip in anterior view presenting an ovoid flattened platform above, with a mesial knob between this and the chin-like lower margin projecting above the soft tissue connecting organ to floor of mouth. Posterior nostril elliptical, with low rim, in part

denticulate, its length twice or more its distance from orbit. Anterior nostril half as large or less, more or less circular, with elevated rim minutely crenulate.

Head without normal scales, much of it smooth usually with cutaneous pores, rugose or irregularly faveolate; with complex systems of plates, ridges, elevations and spines, only the most prominent noted here. Plates: two elongate lozenge-shaped, above front half or more of eyes, extending forward in advance of nostrils; inserted between the hind half of these the apex of a triangular plate extending back to level of hind border of orbit and continuing forward in a short double row then a single bead-like row of small contiguous subspherical nodules terminating anteriorly in a fanlike group extending to upper lip; a somewhat concave plate bordering eye from posterior nostril to about the same horizontal level behind, subcontinuous along its hunder half with a curved plate beginning above pupil and ending acutely at base of prominent spine adjoining lateral line. Ridges: from a small group of spines flanking on either side the fanlike group of nodules near upper lip one short arc to below anterior nostril, one backward to delimit externally the lozenge-shaped interorbital plate; one forming posterior border of hindmost plate, terminating in a spine immediately behind opercular border at origin of lateral line; one constituting the subvertical upper limb of preopercular border, connected at junction with lower limb with a short ridge ending in a prominent spine (largest on head) directed back and a little down; one delimiting much of free opercular border, the operculum itself with a low ridge running back and down across its upper one-third and projecting beyond margin as a strong spine (distant from spine near lateral line origin by rather more than half an eye diameter, from preopercular spine by about two diameters), the area above this ridge and the area below it each wholly covered with a fan of strong minutely spinate striae; interoperculum wholly ridged, margin denticulate; preorbital fluted, margin minutely spined. Spines, additional to those noted above: several irregular spines or groups of spines on orbit, particularly on its posterior half; several small bony shelves, their free margin more or less spinuliferous, a constant one immediately above and in front of upper end of opercular border — some differences between two sides of fish.

Scales with free border irregularly scalloped, with up to a score of variably sized spines, rest of exposed surface with stout spines, modally about a dozen, all large or mostly large with some smaller subequal to largest marginal spines. Scales extending on to bases of caudal rays in two small contiguous patches, very briefly on to pectoral and ventral. A narrow band of heavily spined specialized scute-like scales along dorsal base (best developed below rays) and anal base (about a score, mainly uniserial). Abdominal scutes 13,15, extending from shortly behind the small urinogenital papilla (behind and virtually contiguous with the external anal sphincter) to short of first anal spine by an interval equal to 2-3 scute bases; each scute with a strong pungent mesial spine flanked on either side by a moiety of the strongly ridged and denticulate hind border of the scute; greatest height above base of scute about equal to pupil diameter.

Waite in reporting on the *Thetis* individual, taken off Newcastle in 77-88 m "which adds a new species to the Australian fauna" observed, "It may be noted that the first scute is provided with two spines, which lie one on either side of the first median series, a character not shown in the figure quoted [Günther (1887 pl.25 fig.A)], nor mentioned in Johnston's description". With 17 *Endeavour* specimens from Bass Strait and Oyster Bay, Tasmania, at hand McCulloch (1911) remarked "I find from twelve to sixteen scutes and the first either divided or single, and with one median or two lateral spines". Examination of our material suggests the lateral spines are nothing other than the uppermost spine of the extensive marginal series sufficiently enlarged above its neighbours to invite separate recognition. Such specially developed spinules are barely recognizable in (a) but are apparent in the anterior half dozen scutes of (b): their prominent presence is evidently adventitious.

Aspects of Form

Head, length to vent, standard length. The quite exceptional location of the vent, between the ventrals just behind the head, far in advance of anal origin (in these specimens by 0.29 of standard length), negates the possible existence of any of the patterns

commonly encountered in which in a logarithmic metric the lengths of these three regions fall collinear when graphed on early natural numbers (modally 1 2 3) — a configuration that, its mathematical simplicity would suggest, is presumably to be interpreted as an expression of some profound morphological Gestalt. With the present material it is found the logarithmic lengths are satisfactorily specified (*t* 31.793* 36.947*) with as abscissal values the logarithms of 10 9 1, respectively, the slopes of the best straight lines being −0.4741, −0.4649, the intercepts 3.0002,2.9998, predicted (in parentheses measured) lengths, *TLs*, being 336(333), 353(356, 1 003(1 000) and 343(345), 360(358), 996 (1 000). Whether this relation, differing so markedly from the customary "obvious" early-number relation with positive slope, represents the outcome of some comparatively simple and basic elan of growth, or is an arbitrary specification, formally efficiency, remains unresolved.

Location of vertical fin origins and terminations. In a loglog plot {length to dorsal origin, to anal origin, to (second) dorsal termination, to anal termination, to caudal origin} fall collinear with statistical significance (*t* 99.899*** 72.055**) on {2 5 6 7 10}, the relevant equations being:

Log *L* = 0.5665 log *N* + 2.4263; calculated (measured) lengths, *TLs*, 395(400) 664(644) 736(741) 804(800) 984(1 000).

Log *L* = 0.5934 log *N* + 2.4029; 381(384) 657(649) 732(719) 802(804) 991(1 000).

It may be noted that the case of the second trachichthyid reported from Tasmanian waters, *Trachichthys australis* Shaw & Nodder, 1799 occurring in local catalogues from that of Lord (1923) onward would appear probably to present a comparable length-number fin pattern to that specified above. In an account, with figure, of the single Victorian example of Shaw & Nodder's species that had come under his notice M'Coy (1886, p.57, pl. 114) gave among other dimensions lengths to origins of dorsal, anal and caudal (last as *Ls*), and in a loglog plot these three dimensions are significantly collinear (*t* 13.595*) on {2 5 10}, as found above. At the same time the markedly less elongate form of *Trachichthys australis* results in much higher relative lengths to vertical fin origins (D. 639 *TLs cf.* 400 384, A. 837 *cf.* 664 649), while with the subcircular outline of the fish in advance of the caudal peduncle diminishing the difference between D. and A. origins (198 *TLs cf.* 264 265), the slope of the loglog length-number graph becomes less (0.28 *cf.* 0.57 0.59) with concomitant increase in magnitude of the intercept (2.72 *cf.* 2.43 2.40).

A comparison of the patterns of location of vertical fin origins and terminations noted above for *Beryx decadactylus* and *Centroberyx affinis* with that for *Paratrachichthys trailli* leads to the recognition of a striking relation between them, it becoming evident their diversity can be neatly accounted for as resultant upon simple permutations of the integral numbers in the length-number pattern. In the subjoined formulation the addition, in lower case, or *o* or *t* to the upper case letter conventionally employed to designate the fin (*e.g.*, *D* for dorsal, here with refinement D_1 first dorsal D_2 second dorsal) denotes length to origin or length to termination of that fin. With lengths and serial numbers both in logarithms the situation, as represented by the present material, is as follows:

	1	2	3	4	5	6	7	8	9	10
Beryx decadactylus			D_1o		*Ao*	D_2t			*At*	*Co*
Centroberyx affinis			D_1o		*Ao*		D_2t	*At*		*Co*
Paratrachichthys trailli		D_1o			*Ao*	D_2t	*At*			*Co*

Thus in all three species the relative positions of anal and caudal origins are constant. With the first species taken as standard, first dorsal origin is displaced one unit forward in the third species, second dorsal termination (*i.e.*, termination of the continuous fin) is displaced one unit backward in the second, while anal termination is displaced in the second species one unit in the third species two units forward. These simple whole-number translations adequately specify the variation in fin disposition encountered in the three species as samples. See fig.1.

It may be remarked that in the above equations specifying the location of the vertical fins the parameters of those for the two examples of *Paratrachichthys trailli*,

0.5665,2.4263 and 0.5934,2.4029, are quire similar to those reported earlier for *Beryx decadactylus*, 0.5863,2.3798. Thus when the variates for the two species (being for *P traill*the geometric mean) are plotted together the entries for the two species for *Ao D t* and *Co* on 5 6 10 are virtually coincident (on 10 necessarily coincident), while the single-species values for *D o* and *Ao* on 2 3 7 9 are very close to being collinear with them, the graph for the pooled 10 variates being linear at t 33.225***, with the percentage differences of predicted from given measurements (*TLs*) extremely small, being for *P. trailli* 0.5-3.1 (mean 1.4) for *B. decadactylus* 1.3-3.3 (mean 2.0). However, the parameters for these two species differ markedly from those for *Centroberyx affinis*, for which the geometric means are 0.7033 ± 0.0100, 2.2963 ± 0.00974.

Dorsal spines. These are damaged in the smaller individual, while in the larger all save the second are intact, their lengths increasing backward, the length-number relation being an exponential one $L = bN^k$, common for ascendant sets of radial elements; k 0.3930 log b 4.805; t 9.322**; calculated (measured) lengths, *TLs*, 48(49) -(-) 74(71) 83(80) 90(95).
Anal spines. The logarithmic lengths of the 3 anal spines are a linear function of logarithms 1 2 4.

Log L = 1.3451 log N 1.2249; t 18.490*; calculated (measured) lengths, *TLs*, 17(16) 43(45), 108(105).

Log L = 1.3249 log N + 1.2492; t 18.984*; 18(17) 44(47) 111(108).

With dimensions given by Johnston (1881, p.56) for the type of his synonymic *Trachichthys macleayi* we find Log L = 0.62 log N + 1.02; t 73.566***; 10(10), 32(31), 99(100).

Ventral rays. In ventral fins with the most frequently encountered formula I, 5 it is usually found the lengths of the rays increase from the 1st — here defined as in Part XIX (1974a) as the postaxial — to the 4th, with the 5th somewhat shorter than the 4th (often subequal to the 3rd) and the spine shorter still; the lengths of the rays being related to their serial numbers as defined as $L = b\,N^k$. It is of interest to note that in this fish with V.I, 6 a comparable pattern is maintained, the 5th ray becoming associated with 1st-4th in the exponential relation with in the larger specimen the preaxial ray (imperfect in the smaller) and in both the spine shorter as usual (spines, *TLs*, 124 133).

Log L = 0.2552 log N + 2.0754; t 7.200**; calculated (measured) lengths, *TLs*; 119(115) 142(148) 157(163) 169(170) 179(172)

Log L = 0.1363 log N + 2.0940; t = 21.253***; 124(124) 136(136) 144(143) 150(151) 155(155).

A difference in slope of the magnitude found here is unusual in two conspecific specimens not differing greatly in overall size.

Precaudal pseudospines. In his account of his synonymic *Trachichthys macleayi* Johnston (1881) observed "Upper and lower margins of the caudal peduncle armed repsectively with 8 and 7 strong adpressed translucent spines." These are the structures discussed above in an account of *Centroberyx affinis*. In our smaller individual there are 7 on each border, while the larger has 8 on each border, 4 of the dorsal series, however, being damaged and not measurable. They are similar to those already described, with the last of either series fully septate, bound throughout its length to the adjacent regular ray, similarly pigmented (dull yellowish with numerous minute red-brown chromatophores), and distinguishable from it only by its lesser length (about one-third) and its spine-like rigidity. The earlier members are more obviously vitreous, though possessing a basal whitish or yellowish partly segmented core, and bearing some (in the dorsal series numerous) chromatophores. As in the other species, the logarithmic lengths are a function of the logarithms of the serial numbers counted caudad. The following are the parameters of the rectified equations for the dorsal and ventral series of the smaller specimen followed by that for the central series for the larger example, all lengths being millesimals of standard length. Slope 0.8757,1.3548,1.2836, intercept 1.0478, 0.7773,0.7971; t 72.394*** 75.006*** 146.837***: predicted (measured) lengths 11(11), 20 (21),29(30),38(37),46(44),53(53),61(63); 15(16),27(27),39(38),53(56),68(68),84(81); 6(6),15(16),26(27),37(37),49(47),63(65),76(78),91(85).

Inspection of the parameters of the smaller fish (in which alone both dorsal and ventral sets are measurable) shows that while the dorsal slope is much less than (0.65) the ventral, the dorsal intercept is much greater (1.35). The net effect of these two contrasting ratios is to bring the areas under the graphs into approximate equality, the mean areas per panel (*i.e.*, between adjoining spines), with lengths measured as millesimals of standard length and serial extensions in common logarithms, being 0.20 and 0.19; for the dorsal set for the second specimen 0.17. Otherwise expressed, though the size of the set may differ (*N* = 7 7 8) and though the length of both the first members (1.5,0.8,1.0 mm or 11.1,5.9,6.0 *TLs*) and of the last (8.5,11.0,14.2 mm or 63.0, 81.5,84.5 *TLs*) exhibit considerable variation, the mean logarithmic length of the spine relative to length of fish remains significantly constant, namely 1.51,1.49,1.54.

Coloration

The color of the fish in life is noted in the Handbook as being "reddish purple with yellow fins". The smaller of our specimens, preserved in alcohol, is faintly purplish brown with on the left side some four-fifths of trunk and tail and on the right side some small patches silvery; head except for operculum off-white. Except for dark brown on the operculum and some yellowish in the mouth region, the larger is an indefinite greyish fawn, somewhat more brownish above the lateral line. In both the fins are more or less evenly yellowish; some duskness on caudal.

Family APOGONIDAE

The Cardinal Fishes are represented in Tasmania by 5 species: (1) *Dinolestes lewini* (Griffith, 1834) (2) *Siphamia cephalotes* (Castelnau, 1875) (3) *Lovamia fasciata* (Shaw, 1790) (4) *Vincentia novaehollandiae* (Valenciennes, 1832) (5) *Gronovichthys lemprieri* (Johnston, 1883) (type locality Dunkleys Point, Tasmania). A further species, *Apogon guntheri* Castelnau 1872, that appears in the second list by Johnston (1891) is treated in the Check-List (McCulloch 1929) as a queried synonym of (4) (referred to the genus *Apogon* Lacépède, 1802) and in the Handbook (Munro 1960) is formally accepted as identical with that species (along with *Apogon conspersus* Klunzinger, 1872, *Vincentia waterhousii* Castelnau, 1872, *Mionorus ramsayi* Fowler, 1908 — referred in the Check-List to *Apogonichthys* Bleeker, 1854 — and (5), see below.)

In some recent texts — *e.g.*, Scott (1962) Whitley (1962) Marshall (1964) Scott, Glover & Southcott (1974) — (1) is referred to the monotypic family Dinolestidae, which, however, is not recognized as distinct by Greenwood *et al.* (1966) in their provisional classification of living teleosts. In the Handbook (5), described in *Apogon*, is accommodated in *Vincentia* Castelnau, 1872, and identified with (4). However, there are good grounds for regarding Johnston's Tasmanian species as valid — see Part XII (1964), which carries a full description with figure, Part XVII (1969), Part XX (1974b), which reports a local example of (4), and Part XXIV (1978), which advances reasons for transferring it from *Apogon* through *Vincentia* to *Gronovichthys* Whitley, 1929. The Tasmanian species were keyed in Part XII, but as pointed out in Part XX the specification of the spines of the second dorsal involves an error, while the receipt of additional material has shown the distinction there drawn between (4) and (5) in respect of size of interorbital relative to eye cannot in all cases be relied on, the primary point of distinction between these two forms being that the dorsals are united in the former separate in the latter.

Genus *DINOLESTES* Klunzinger, 1872

Dinolestes Klunzinger, 1872, p.29. Type-species, *Dinolestes mulleri* Klunzinger.
Neosphyraena Castelnau, 1872, p.96. Type-species, *Neosphyraena multiradiata* Castelnau.
Lanioperca Günther, 1872, *Ann. Mag. Nat. Hist.*, 4(10), p.183. Type-species, *Lanioperca mordax* Günther.

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Dinolestes lewini (Griffith, 1834)

Esox lewini Griffith, 1834 *in* ANIM. KINGD. (Cuvier), 10, p.465, pl.60. Type locality: New Holland (Lewin).
Dinolestes mulleri Klunzinger, 1872, p.30, pl.3. Type locality: Hobsons Bay, Victoria.
Neosphyraena multiradiata Castelnau, 1872, p.97. Type locality: Melbourne Market.
Lanioperca mordax Günther, 1872, *Ann. Mag. Nat. Hist.*,4(10), p.183. Type locality: Tasmania (Allport).

Remarks

This species has the distinction of having had three genera established for it in the one year (in Germany, Australia, England): in Tasmania, which provided the type locality for Günther's genus, the type material being forwarded to England by Morton Allport, it is not uncommon. Listed under Günther's name and placed in Sphyraenidae by Johnston in both his catalogues (1883, 1891) it was entered under *Dinolestes lewini* (genus Klunzinger, species Griffith) in the later lists of Lord (1923, 1927) and Lord & Scott (1924) being there transferred to Apogonidae. It has been reported from all Australian States other than Queensland. It differs clearly from all other Australian apogonids in having more numerous dorsal rays (18-19, *cf.* maximum 11, mode 8 or 9), anal rays (25-26 *cf.* maximum 15 mode 8 or 9), lateral line scales (64-67 *cf.* maximum 50 mode 20-30) and in reaching a greater length (500 mm *cf.* maximum 250 mode about 50-80): by some recent Australian authors – *e.g.*, Whitley (1962) Scott (1962) Scott *et al.* (1974) – it is referred to a monotypic family, but is retained in Apogonidae in the Check-List (McCulloch 1929) and the Handbook (Munro 1960). The close superficial resemblance of this fish to the widely distributed sea pikes or barracudas led early writers – *e.g.*, Castelnau (1872) Macleay (1881) Johnston (1891) – to associate it with them in the family Sphyraenidae, a taxon of different subordinal (or, according to authors who place it in the Mugiliformes, ordinal) rank from the Apogonidae. Vernacular names: long-finned pike, long-finned sea pike, skipjack – more commonly applied to *Pomatomus saltator* (Linné, 1766) – Tasmanian jack.

Material

Eight specimens, *Ls* 192-317 *Lt* 227-380, collected by scuba divers at an interstate competition at Croppies Point near Bridport, 28 December 1973 (Q.V.M. Reg. No. 1974/5/158). The coefficient of variation of standard length (16.5) appears somewhat high for a wholly homogeneous size group for which values of ⩾10 are usual: however, no obvious mode of dissection of the sample presents itself.

Meristic Characters

D. V; I, 17(2)-18(6): in 1 example with 17 rays and 2 with 18 the last ray is divided to base. A. II, 25(1) 26(2) 27(3) 28(2): in 2 examples with 27 rays and 2 with 28 the last ray is divided to base (one specimen with anal imperfect). P. 16(3) 17(4) 18(1: both right and left fins). V. I, 5. L. lat. 63(1) 64(1) 65(3) 66(1) 67(1) 70(1).

In several cases these counts involve more or less marked emendation of local published accounts, of which the more significant are that of Castelnau (1872) of his *Neosphyraena multiradiata* (measured specimen cited 0.39 m) that of M'Coy (1886) with figure (pl.115) and dimensions of a Victorian example of total length 0.495 m and the synoptic notice of the Handbook (Munro 1960). Spines of the first dorsal are constant at 5, though, as pointed out by M'Coy, the figure by Klunzinger (1872) has only 4, while the photograph in Tenison-Woods (1882) does not show the first dorsal at all, "the error in both cases probably arising from the ease with which the spines are completely concealed when depressed into a deep slit or groove at the base of the fin" (p.62). Spines of the second dorsal are noted at 2 by M'Coy, the Handbook admits 1-2, while Castelnau gives a total of 17-21 elements, observing in a footnote "It would be more exact to say that the two first rays of the second dorsal are not branched, and could be called spines if they were not soft; the following (third) ray is much longer". The lower second dorsal ray count of 17 falls outside the Handbook's range, 18-19. Anal ray counts in 5 individuals here exceed by 1-2 the maximum of 26 found in the Handbook and in M'Coy (Castelnau notes

"twenty-eight rays" but his convention in this context appears to take account both of spines and soft rays). Pectoral counts in 5 specimens exceed by 1-2 the 16 given by all three authors cited above; while the lateral line range 63-70 transgresses at both limits the Handbook's synoptic 64-67 (Castelnau's "about seventy-five scales" appears clearly to be no more than a rough approximation).

Dimensions

Morphometric data on this species are few and local accounts do not provide measurements of more than a single fish. A series of dimensions of each of the present 8 individuals is set out in table 4, measurements other than that of standard length being recorded as millesimals of standard length.

TABLE 4

Dinolestes lewini (Griffith, 1834)

Dimensions of eight specimens, Croppies Point, near Bridport, Tasmania (Q.V.M. Reg. No. 1979/5/158). First entry standard length, *Ls*, in mm, all other entries as millesimals of standard length.

Feature	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Standard length (lth), mm	192	219	260	266	280	289	317	317
Lth to end of upper caudal lobe	1 172	1 142	1 158	1 135	1 182	1 166	1 186	1 192
Lth to end of lower caudal lobe	1 182	1 171	1 165	1 139	1 200	1 180	1 196	1 199
Lth to end of middle caudal rays	1 104	1 089	1 123	1 086	1 125	1 131	1 132	1 114
Lth to first dorsal origin	406	-	415	398	421	394	420	391
Lth to forst dorsal termination	432	-	438	444	464	429	426	426
Lth to second dorsal origin	589	584	608	575	625	557	584	587
Lth to second dorsal termination	750	753	773	763	790	772	803	779
Lth to anal origin	531	575	585	539	607	588	599	577
Lth to anal termination	849	815	850	818	854	834	864	852
Lth to vent (middle)	505	553	550	498	561	545	563	533
Lth to ventral origin	323	338	362	331	350	315	341	328
Lth (total) of ventral	128	128	127	124	132	114	123	120
Lth to pectoral origin	281	292	304	289	307	308	325	290
Lth (total) of pectoral	156	151	158	164	171	152	162	158
Head	292	292	308	299	314	322	338	306
Snout	130	128	135	124	136	125	142	136
Eye	52	53	50	53	46	45	50	47
Orbit	60	64	56	60	57	62	60	54
Interorbital	47	46	50	-	47	49	54	54
Depth at front of eye	109	100	112	-	107	118	111	139
Depth at back of eye	125	132	131	-	132	149	139	167
Depth at opercular border	161	160	185	177	175	166	189	174
Depth at vent	188	183	188	188	196	173	186	200
Maximum depth	198	187	196	192	204	176	196	202
Depth of caudal peduncle	96	100	89	91	93	92	95	98
Lth of longest dorsal spine	42	-	46	43	44	38	-	38
Lth of longest dorsal ray	146	162	140	120	139	114	122	132
Lth of longest anal ray	161	148	131	110	121	104	110	103
Lth of longest ventral ray	120	118	100	102	106	93	95	99
Lth of longest pectoral ray	135	179	137	133	108	142	156	145

Proportions

Each of the proportions noted below gives in succession range, mean with standard error, coefficient of variation with standard error, with the addition in parentheses of values derivable from M'Coy's single specimen, Castelnau's account, and Munro's synoptic data where these items are available.

Head in standard length 3.0-3.4 3.26 ± 0.05 4.3 ± 1.1 (3.3, three and two-thirds in total length, 3.4-3.5). Maximum depth in standard length 4.9-5.7 5.16 ± 0.09 4.7 ± 1.2 (5.1, about six and a half in total length, 4-6.5). Eye (horizontal) in head 5.6-7.2 6.27 ± 2.08 9.4 ± 2.4 (orbit 5.2 6.2 5.5). Eye (vertical) in head 4.6-5.7 5.43 ± 0.19 7.5 ± 1.9. Eye in snout 2.4-2.9 2.67 ± 0.08 7.9 ± 2.0 (— — 2.5). Eye in interorbital 0.9-1.1 1.00 ± 0.03 7.9 ± 2.0 (— — "equal"). Pectoral in head 1.8-2.4 1.99 ± 0.07 10.0 ± 2.5 (2.2 2.5 —). Ventral in head 2.3-3.2 2.55 ± 0.12 12.7 ± 3.3 (3.3 3.4 —). Depth of caudal peduncle in head 3.0-3.5 3.3 ± 0.08 6.8 ± 1.7. Longest dorsal spine (6 entries only) 6.7-8.5 7.39 ± 0.29 9.6 ± 2.4, longest dorsal ray 1.8-2.8 2.34 ± 0.12 15.0 ± 3.9, longest anal ray 1.8-3.1 2.57 ± 0.17 18.8 ± 5.1, all in head.

The second and third of the last three ratios each exhibit significant positive correlation with standard length, r 0.793 (z 1.075) t 3.187*, r 0.942 (z 1.760) t 6.907***: this systematic variation of ray length in dorsal and anal with head length (and hence with standard length, with which head length is correlated at r + 0.984) has not previously been noted. The six entries of the longest spine ratios also show positive correlation with head length but not at a formally significant level (r 0.645 z 0.767).

Aspects of Form

(1) Length of head, length to vent, standard length. In this species, as in many others of considerable taxonomic diversity, the anteroposterior extensions of the basic regions head, head + trunk, head + trunk + tail exhibit the relation $L = b\,N^k$ where L = regional length, N = an early natural number, the present set being {1 2 4}: the relation is conveniently rectified as $\log L = k \log N + \log b$. For the mean lengths for the sample the best straight line is:

Log L = 2.4852 log N + 0.8475; t 32.154*; calculated (measured) lengths, *TLs*, 309(309),550(539) 990(1 000).

Parameters of equations for the eight individual fish together with indications of statistical significance and with calculated and measured values are set out in table 5.

TABLE 5

Dinolestes lewini (Griffith, 1834)

Parameters of the equation $\log L = k \log N + \log b$ where L = {length of head length to vent standard length} N = {1 2 4} together with significance and with calculated (measured) lengths as millesimals of standard length, *TLs*: eight specimens from Croppies Point near Bridport, Tasmania.

Specimen	Standard length, mm	k	log b	t	Calculated (measured) lengths, *TLs*
(a)	192	0.8880	2.4556	15.661*	285(292) 528(505 978(1 000)
(b)	219	0.8880	2.4687	145.936***	294(292) 545(553) 1 008(1 000)
(c)	260	0.8495	2.4872	354.524***	308(308) 553(550) 997(1 000)
(d)	266	0.8709	2.4621	11.183	290(299) 530(498) 965(1 000)
(e)	280	0.8356	2.4971	1124.598***	314(314) 560(561) 1 006(1 000)
(f)	289	0.8174	2.5020	24.311*	317(322) 560(545) 987(1 000)
(g)	317	0.7824	2.5243	29.249*	334(338) 575(563) 989(1 000)
(h)	317	0.8542	2.4803	23.803*	302(306) 546(533) 988(1 000)

(2) Origins and terminations of vertical fin systems. Lengths to dorsal origin, anal origin, (second) dorsal termination, anal termination, and standard length fall significantly collinear on a loglog grid with as abcissae five integers {3 5 7 8 10}. For mean lengths for the sample (seven entries only for lengths to dorsal origin and anal termination) the best straight line (sum of logarithmic, not arithmetical, deviations from mean minimized) is:

Log L = 0.7554 log N + 2.2435; t 37.543***; calculated (measured) lengths, *TLs*, 401.7 (406.4),605.0(575.1),761.9(772.6),842.8(842.0),997.5(1 000).

Data for individual specimens are recorded in table 6.

TABLE 6

Dinolestes lewini (Griffith, 1834)

Parameters of the equation $\log L = k \log N + \log b$ where L = {length to dorsal origin, to anal origin, to (second) dorsal termination, to anal termination, to caudal origin (*Ls*)} N = {3 5 7 8 10}, together with significance and with calculated (measured) lengths as millesimals of standard length, *TLs*: seven specimens from Croppies Point, near Bridport, Tasmania.

Specimen	Standard length, mm	k	$\log b$	t	Calculated (measured) lengths, *TLs*
(a)	192	0.7721	2.2215	12.891**	389(406) 570(531) 748(750) 829(849) 985(1 000)
(c)	260	0.7377	2.2616	133.217***	411(415) 599(585) 767(773) 847(850) 998(1 000)
(d)	266	0.7758	2.2164	16.571***	386(398) 574(539) 745(762) 826(818) 981(1 000)
(e)	280	0.7192	2.2808	1030.985***	421(421) 607(607) 774(790) 852(854) 1 000(1 000)
(f)	289	0.7724	2.2285	210.242***	395(394) 587(588) 761(772) 843(834) 1 002(1 000)
(g)	317	0.7339	2.2724	103.268***	399(420) 610(599) 781(803) 861(864) 1 015(1 000)
(h)	3.7	0.7908	2.2144	128.122***	391(391) 585(577) 763(779) 848(852) 1 012(1 000)

(3) Ventral rays 1-4. The ray lengths are regularly 1<2<3<4>5, ray 1 being defined as in Part XIX (1974a, p.248) as that farthest from the spine (nearest to medioventral line of fish; postaxial). As is usually the case with this very common pattern the lengths of rays {1-4} are collinear in a loglog plot with their serial numbers. The relevant best straight line has been calculated for the largest specimen (h):
Log L = 0.0832 log N + 1.4487; t 10.549**; calculated (measured) lengths, mm, 28.1(28.0) 28.8(29.9) 30.8(31.0) 31.5(31.3)

Family SCOMBRIDAE

Greenwood *et al.* (1966) in their provisional classification of living teleosts assemble in the wide taxon Scombridae six or eight groups treated by most Australian authors as separate families. The species here dealt with, the butterfly mackerel, *Gasterochisma melampus* Richardson, 1845, was placed first by McCulloch (1922) in Scombridae later (1929) in Scomberomoridae, in which it was accommodated also by Whitley (1962); however, in the Handbook (Munro 1958) it is referred to Gasterochismatidae (rendered Gasterochismidae by Greenwood *et al.* in their synonymy). In all Tasmanian lists it appears in Scombridae.

Genus *GASTEROCHISMA* Richardson, 1845

Gasterochisma Richardson, 1845, p.346. Type-species, *Gasterochisma melampus* Richardson.
Lepidothynnus Günther, 1889, p.15. Type-species, *Lepidothynnus huttonii* Günther.

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Gasterochisma melampus Richardson, 1845
(pl.1)

Gasterochisma melampus Richardson, 1845, p.346. Type locality: Port Nicolson, New Zealand.
Gasterochisma melampus Richardson, 1846, p.60, pl.37.
Lepidothynnus huttonii Günther, 1889, p.15, pl.6, figs A,A'. Type locality: Lyttleton, New Zealand.
Lepidothynnus huttoni [*sic*]: McCulloch, 1929, p.265.
Gasterochisma melampus: Johnston, 1883, p.118 and 1891, p.11 and Whitley, 1929, p.60: Waite, 1912, p.220, pl.8: McCulloch, 1922, p.104, pl.48, fig.287a, 1929, p.265: Lord, 1923, p.70, 1927, p.15: Lord & Scott, 1924, pp.12,79, unnumbered fig.: Munro, 1958b, p.110, fig.740: Whitley, 1962, p.184, unnumbered fig.: Scott, 1979, p.119.

Tasmanian Occurrence

In including *Gasterochisma melampus* in his first catalogue Johnston (1883, p.118) noted the recent capture [by the schooner *Malcolm*] of an example at the mouth of the estuary of the Derwent and reported its meristic characters together with a dozen dimensions. Johnston's fin counts were included in his memoranda made available by Whitley (1929), being there accompanied by a newspaper cutting that repeated the catalogue measurements, adding "width of widely forked tail at tips 12 inches" (305 mm) and rendering total length and 'length of body' (*i.e.*, length without caudal) as 1022 mm and 889 mm as against 991 mm and 838 mm in the memoranda and in the catalogue. This record appears to have provided the sole basis for the presence in the local lists of Lord (1923, 1927) and Lord & Scott (1924) of this "very rare oceanic species" (McCulloch 1922, p.104) that occasionally comes ashore. Though having a wide range it has not hitherto been listed from Western Australia (Whitley 1948) or South Australia (Scott *et al.* 1974). An example, *Ls* 372 *Lt* 459, stranded at Falmouth on 14 November 1978 was reported in Part XXV (1979). Two other Tasmanian specimens are here noted — *Ls* 460 *Lt* 578, collected by Mr Shane Down 3.2 km east of Binnalong Bay in March 1980 (Q.V.M. Reg. No. 1980/5/35), *Ls* 342 *Lt* 417, trolled in 70-90 m about 8 km off the south of the Mersey River by Mr K.W. Spilstead in mid June 1980 (Q.V.M. Reg. No. 1980/5/59). These individuals are denoted (a) (b) (c) in order of ascending standard length.

In quantitative statements below entries for the Queen Victoria Museum's three examples are cited, where appropriate, in order of ascending magnitude of *Ls*, with variates for the specimen reported by Johnston, the largest individual, shown where available in parentheses.

Meristic Characters

D. XVII XVI XVI; I, 9 9 10; 6 8 7 finlets. A. I II I, 9 10 10; 6 8 6 finlets. P 23 22 22. L. lat. 65, not traceable beyond level of second dorsal finlet 74 —. L. tr. 8/20 7/21 7/20. Caudal about 18 + 18 rays + 4/5 strong spine-like procurrent rays — —.

Gill Rakers

The Handbook (Munro 1958b, p.110) states "G.R. absent", Whitley (1962, p.185) has "no gill-rakers"; however, in a more qualified statement, Waite (1912, p.222) wrote "no distinct rakers are developed, their place being taken by curved spines, irregularly disposed". Of the Falmouth specimen it was noted "While there are no elongate rodlike structures, the anterior arch bears 11 small spinulose mounds, placed about their own diameter, 2 mm, apart at the middle of the series, closer together at the ends". In the present material the arrangement is essentially similar. In the Binnalong Bay individual several mounds at the inferior end of the series are in contact, their distal borders effectively continuous and a precise determination of their number becomes somewhat arbitrary; if 3 are counted in this region the total number on the lower limb of the anterior arch is 13: in the northwest coast individual, 14. Each mound bears from half a dozen to a dozen curved spines, in some only on the free upper surface in others extending on to the proximal part, being here usually smaller. There is some difference in size of the major spines in the present two specimens, those of the larger fish being

relatively larger. Thus the spines are borne on discrete structures, not "irregularly disposed" as assessed by Waite, and these mammilliform structures would clearly appear, by their location number and character, to represent rudimentary or vestigial rakers.

Dimensions

The principal dimensions are recorded below as millesimals of standard length; of the two versions of standard length reported for the early Derwent estuary specimen (see above) the smaller, 991 mm, given by Johnston himself (1883, p.118) has been accepted. Length to tip of upper caudal lobe 1219 1931 1257 ("total length" 1182), to tip of lower caudal lobe 1211 1204 1226, to end of middle caudal rays 1053 1054 1087. Length to origin termination of first dorsal 275 253 287 605 556 570, of second dorsal 635 594 628 (579) 725 719 715, of anal 646 632 663 (657) 731 723 740. Length to vent (middle) 620 613 653. Length to origin of pectoral 254 250 272, of ventral 251 250 257. Total length of pectoral 127 123 133 (150), of ventral 264 284 270 (364 — , ventral correctly noted in memoranda (Whitley 1929, p.60) but rendered "anal" in catalogue). Length to origin of upper caudal lobe 961 949 980, of lower caudal lobe 959 962 985.

Head 250 242 254 (250). Snout 99.4 92.7 104 (114). Eye, horizontal diameter 31.9 29.8 30.4 ("eye" 25.0), vertical diameter 33.6 32.5 32.6. Interorbital 76.0 67.2 73.9. Depth at front of eye 155 153 154, at back of eye 187 188 187, at opercular border 243 263 333, at vent 243 245 228; maximum 275 277 261 (257 — in newspaper cutting "at shoulder"), depth of caudal peduncle 37 38 35 (29 — in catalogue "least depth"). Width at same points 73 83 76, 79 91 96, 99 108 107, 79 99 80; 110 118 113, 26 47 21. In first dorsal length of first spine 38 43 39, of longest intact spine 108(9th) 123(8th) 96(11th), of last spine 20 32 37; in second dorsal length of spine 37 57 57, of first ray 67 — 79, of longest ray 76(2nd) 64(3rd longest intact) 79(1st), of last (shortest)ray 19 21 17, longest (last) finlet 47 54 43. Anal spine 52 30(first) 39, first ray — (second 44) 47(longest) 85(longest), longest (last) finlet 53 54 -.

Proportions

Greatest depth 3.6 3.6 3.8 3.9 (Handbook, Munro 1958b, 3.9-4.1), head 4.0 4.1 3.9 (4.0) (Handbook 4-4.1) in standard length. Depth of caudal peduncle in head 6.8 6.4 6.4. Eye, horizontal, in head 7.8 8.1 8.4 ("eye" 10) (Handbook "eye in head" 5.5-7.4). Eye, horizontal, in snout 3.1 3.1 3.0 ("eye" 4.6), in interorbital 2.4 3.3 2.4. Pectoral in standard length 6.5 6.6 6.0 (6.7), in head 1.6 1.6 1.5 (1.17). Ventral in standard length 3.1 2.9 3.1 (6.1), in head 1.3 1.4 1.3 (1.5). First dorsal base (to last spine) in standard length 3.0 3.3 3.4. Second dorsal base (to last ray) in standard length 11.0 8.0 10.3. Anal base (to last ray) in standard length 10.7 10.9 13.0.

General Features

Maxilla to below 0.5 0.4 0.3 eye ("front margin of eye", Waite), its greatest oblique width 17 15 21 *TLs*, its exposed length short 0.28 0.33 0.33 mouth cleft, shortest distance from eye 14 17 21 *TLs*. Upper jaw projecting very slightly, mouth cleft at an angle of about 25°-30° (contrast Waite, "horizontal"). Teeth in jaws minute subconical relatively stout, somewhat variable in size, uniserial, on palate similar rather more slender directed somewhat backward, on vomer in a kite-shaped patch. Posterior nostril a short downwardly and backwardly oblique slit, its length subequal to its distance from orbit. Anterior nostril small round aperture about on horizontal level with superior orbital border and inferior border of upper lip, direct distance from lip 1.3 1.1 1.0 that from orbit ("midway", Waite). Border of ventral fin somewhat irregular, grossly slightly concave (shown strongly convex by Richardson, strongly concave by Waite almost straight by Günther), ray lengths 1>2<3<4=5 1>2<3>4<5 1>2>3>4<5 (ray 1 farthest from spine), preaxial ray 1.3 1.1 1.2 postaxial ray or 2.0 2.3 2.4 spine, rays in general with three strong rami widely diverging distally remaining separate almost to base. Greatest depth of groove for reception of fin 30 32 37 *TLs*, inner surface fleshy smooth white.

Dorsal originating behind head being by 0.5 eye behind pectoral origin is specimens (a) (c), above hinder part of operculum being 0.5 eye in advance of pectoral margin in (b).

This variation in location of the fin is of interest not only in itself but also as throwing some light on a vexed question. Of Günther's figure of his specimen (1889, pl.6 fig.A), noted as being only a sketch, Waite (1912, p.220) stated "it is evident the dorsal fin is incorrectly shown", possibly, he suggested, to conform to the "wrongly articulated" skeleton (pl.6 fig.A'), which makes "it appear that the fin arises over the opercle instead of at some distance behind it" (the assumption that the latter position is an absolute specification now being shown by our specimens to be invalid): in fact, Günther's text has "above the gill-slit" and his illustration of the fish shows dorsal origin distinctly behind opercular border, about midway between it and pectoral origin, much as in the figure by Richardson (1846, pl.37). For the large Kaikoura example Waite notes dorsal origin "behind the root of the pectoral", his illustration depicting it at level of hind margin of the fin base. With the specifications here reported being exhibited by examples of much the same size it would appear the positioning of the fin origin is subject to mere individual variation, with no evidence to suggest the existence of heterogonic growth such as, for instance, that determining location of dorsal origin in some centrolophids (Haedrich 1967).

Anal originating shortly behind, under middle of second dorsal. Pectoral reaching to below 7th 9th 11th dorsal spine. The later rays of the dorsal and anal increasingly assume the tufted character of the finlets, the last two or three being formally distinguished from these only by being more closely set and by the presence of but feebly developed membrane. Outer rays of the furcate caudal inserted well in advance of hypural joint, reaching forward for an eye diameter or more at least to the front of the penultimate vertebra. Behind the level of their insertion the tail continues back as a scaled tumid fleshy lobe covering the hypural plate (formed by fusion of several hypurals) and reaching nearly to the tips of the short median rays. Scales rounded, a little deeper than long, cycloid; diameter of scale from midflank to about two-thirds that of eye; ceasing on dorsum of head at level of front of orbit, posterior nostril, anterior nostril; preoperculum squamous save for narrow gelatinous arc constituting hind border; operculum without scales but a small subcircular patch of about half a dozen scales just above and in front of it immediately in advance of origin of lateral line; isthmus scales to, or almost to, tip at least to level of front of orbit; rest of head smooth. In his description of the large Kaikoura example (*Ls* 1 473 mm) Waite reported the head as being naked "with the exception of about 4 rows of scales on the cheeks"; a progressive decrease in cephalic scalation would appear probable. Lateral line rising about to level of middle of spinous dorsal, initially abruptly in a short arc subequal to eye diameter then gradually and evenly about to its termination below or just behind rayed dorsal base where its distance from profile is rather less than two eye diameters. A noticeable feature of the compressed head, to which attention has been drawn by Günther and Waite, is the presence of a median dorsal ridge clearly defined from in advance of posterior nostril to above hinder part of preoperculum, lapsing (variably in individuals) forward towards tip of snout backwards towards dorsal origin: this marks the site of the supraoccipital crest of the neurocranium, originating in general in scombrids at the pineal foramen and extending to or beyond the exoccipitals.

Radiograph

By courtesy of the Radiography Department Launceston General Hospital several radiographs were taken of specimen (c) (Plate 1).

Examination of the radiographs and comparison of these by Günther's reproduction of a photograph (1889, pl.5 fig.A') with an articulated skeleton in the Canterbury Museum, Christchurch, New Zealand suggest the following comments. Our fish appears to have about seven more vertebrae (44 *v.* 37) and those in the posterior one-fifth of the series are here somewhat larger relative to the rest. As pointed out by Waite (1912) the articulation has been incorrectly carried out, the origin of the dorsal fin being made to appear too far forward: in our specimen the insertion of the fin at the dorsal profile is vertically over the 6th (*cf.* about 2nd) vertebra and well behind the cranium; the first anal ray is below the 21st (about 19th). The mouth cleft in the Tasmanian example slopes distinctly down and back (extends virtually horizontally).

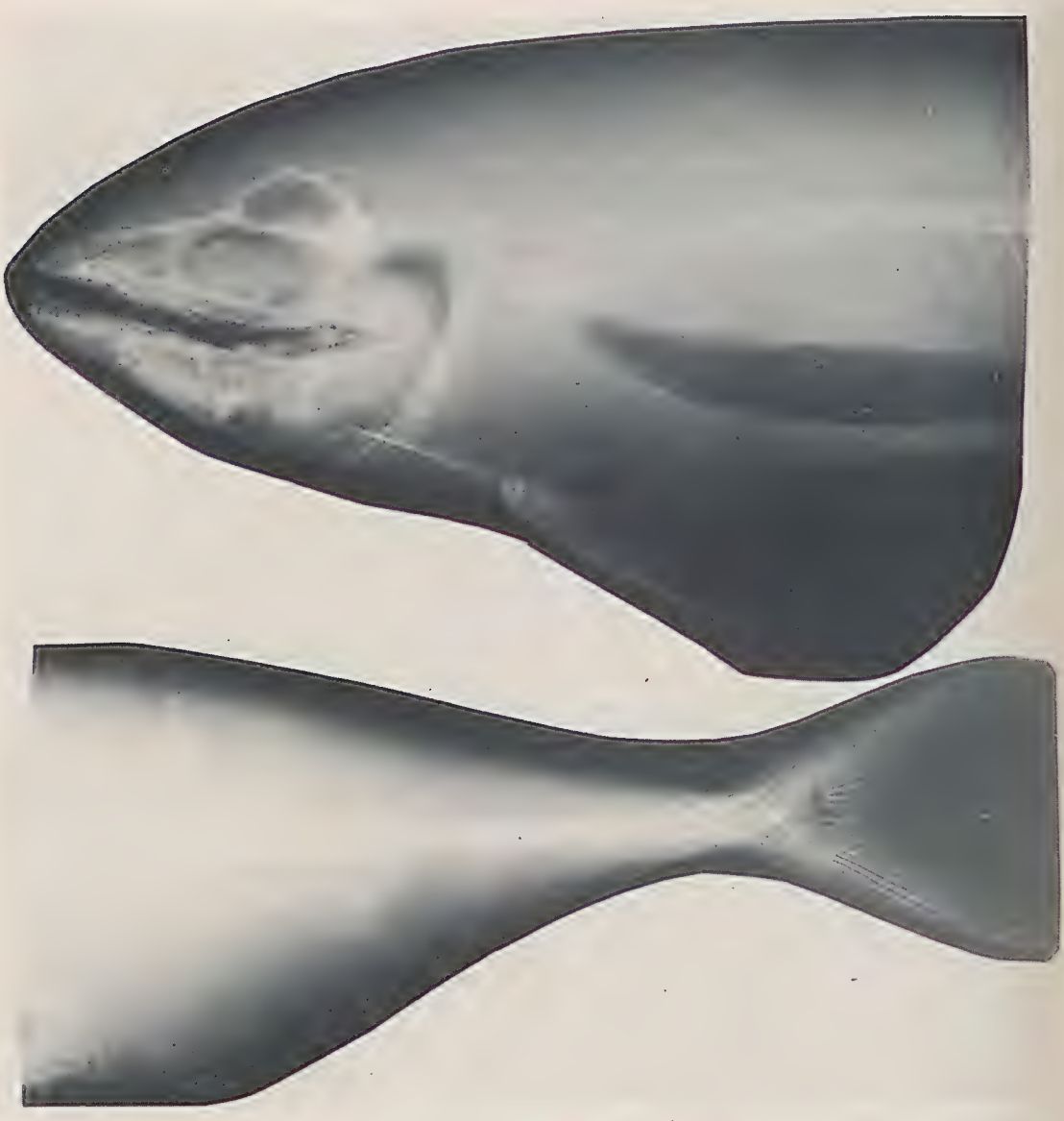

PLATE 1.- *Gasterochisma melampus* Richardson, 1845. Radiographs of anterior and posterior portion of a specimen 342 mm in standard length, 417 mm in total length, collected off the mouth of the Mersey River, Tasmania; (K.W. Spilstead) Q.V.M. Reg. No. 1980/5/59. Radiograph, Launceston General Hospital; print, D.R. Barratt.

While the complete pattern of the caudal complex cannot be determined with certainty, the following features appear to be recognizable: a large subtriangular plate formed probably by the fusion of the hypurals 1-4 (together with 5?); a preural followed by parhypural (? fused with hypural plate; region obscured by intrusion of proximal parts of caudal rays) with moderate parhypurophysis; 4-5 of the upper and 5-6 of the lower caudal

rays extend forward over the hypural plate, the origins of the outermost virtually in contact near the front of the plate, the interval between those of the others rapidly decreasing backward, while the bases of the central rays, 7 of which are the thickest of the total series, stop short of the hind margin of the plate, leaving here in the radiograph a distinct featureless bar (Collette & Chao 1975, p.578, state "One of the diagnostic characters of the Scombridae [*Sarda* Cuvier, 1829 *Gymnosarda*, Gill, 1862 *Orcynopsis* Gill, 1862 *Cybiosarda* Whitley, 1935 *Allothunnus* Serventy, 1948] is that the bases of the caudal rays cover the hypural plate (Figure 57), instead of only extending part way over the plate as is true of Gempylidae and Trichiuridae"); 2 preural centra support, or are level with the bases of, small early caudal rays both above and below.

Variation with Growth

Several notable changes in both quantitative and qualitative characters take place during growth. The chief age-determined morphometric features are (a) a striking decrease in relative length of ventral (b) a less pronounced increase in relative length of pectoral (c) a decrease in height of first dorsal relative to that of second dorsal.

(a) Ventral. This fin is of extraordinary size in the young (its wide membrane expanse suggesting the epithet in the vernacular name, butterfly mackerel); as figured by Richardson (1846) in a small example being almost twice length of head and extending back for a distance equal to the length of the median ventral cleft to reach virtually to the vent, whereas in an adult figured by Waite (1912) it is barely half length of head and reaches less than one-third of distance to vent. Examination of the data for Richardson's type of *Gasterochisma melampus* followed in sequence of increasing size by those for the four Tasmanian examples, the Kaikoura fish (Waite 1912) and the synonymic *Lepidothynnus huttonii* (as measured by Richardson) shows that in six of the seven cases (specimen from near the Mersey estuary the exception) an increase in total length is accompanied by a decrease in relative length of the ventral fin, the total lengths, mm, being 203 417 459 578 991 1 637 1 664, the relative fin lengths, millesimals of standard length, 331 264 284 270 147 97 71, giving r −0.978 (z −2.256), with t 10.234***. While the fin thus undergoes reduction in length the midventral cleft into which it can be withdrawn continues to extend from its origin at the fin base to its termination just anterior to anal origin. With the three fish here reported in ascending order of overall size the length of the ventral is 0.87 0.97 0.85 that of the groove.

(b) Pectoral. - While the relative length of the ventral decreases with age that of the pectoral increases, the degree of change, however, being very much less. With fish in ascending order of *Lt* as above, *TLs* lengths of pectoral are 110 127 123 133 135 149 168 (the northwest coast example again out of sequence): r = 0.932 (z 1.669), t 5.768**. The relevant linear equation for regression of relative fin length on total length (L = 0.029 *Lt* + 110.0) yields predicted lengths differing from measured lengths by 0.8-6.0 mean 4.15 per cent.

(c) Relative heights of dorsals. In the young the height of the spinous dorsal is decidedly greater than, in the adult noticeably less than, the height of the soft-rayed dorsal, approximate ratios with increasing length of fish being for the sample here considered 2.6 2.0 1.5 1.2 <1 (Johnston) 0.7 0.5, the height of the anterior fin being contained about 1.9 2.0 2.1 2.7 – 4.7 6.7 times in length of head. In contrasting the relative heights of the fins in his specimen with the condition as figured by Günther (1880a, p.455) – *i.e.*, after Richardson (1846) – Johnston spoke of his specimen as "mature"; as pointed out by Waite it is of intermediate size and exhibits intermediate values of the size-related features here discussed.

The positions of the dorsals relative to one another appears to be the subject of some confusion. Munro (1958, p.110) states they are "united basally in young, widely separated in adults", and this specification was accepted in Part XXV (1979, p.120). This would appear to be substantiated by the following facts. In Richardson's 200 mm specimen the fins are virtually contiguous, while in the Queen Victoria Museum's three examples and Günther's type of *Lepidothynnus huttonii* as figured (relative total lengths of these fish,

with Richardson's as unity, 2.1 2.3 2.8 8.2) they are separated by 0.11 0.13 0.21 *ca*.0.8 of first dorsal base, or 30 38 78 *ca* 100 *TLs* units: the termination of the first dorsal and the origin of the second dorsal are here taken to be specified by the location of the last spine and the first ray – in the northwest coast fish (after Richardson's the smallest) a low continuous strip of membrane extends the full length between spine and ray. On the other hand it should be observed, first, that Günther's figure is noted as being simply a sketch; secondly, Waite's own figure of the Kaikoura specimen (subequal in length to Günther's fish) depicts the fins as quite closely approximated, the interval being only about 0.1 first dorsal base or some 30 *TLs* units.

Four qualitative features have been reported as exhibiting variation with growth. In older fish there would appear to be some reduction in the scales on the head. In the material at hand they extend forward on the dorsum to level of middle of anterior border of orbit (in Waite's large individual commencing behind the occiput); preoperculum partly or fully scaled, operculum naked. On the ventral surface scales are found on the whole length of the narrow isthmus, which runs forward to a little in advance of level of anterior nostril. The lateral line suffers diminution with age. Figured in the young as terminating in advance of the hinder finlets though described as reaching the caudal, it is here traceable to level of first dorsal finlet in (a) (b) last one-fourth of second dorsal base in (c), while in Waite's individual, about three times as long, it is reported as ceasing below middle of first dorsal. There is some disagreement regarding the presence of absence of lateral keels on the caudal peduncle in this species, and on evidence provided by the present material it would appear the feature is an inconstant one, perhaps without regard to overall size. In his paper on the generic characters of the new species Richardson (1845, p.346) notes "cauda gracilis sine carinis" – a reference to caudal keels doubtless being suggested by the presence of these structures in most of the Scombridae (*sensu lato*, as recognized in the provisional teleost classification of Greenwood *et al*. (1966), including Thunnidae, Katsuwonidae, Scomberomoridae and other groups treated in many Australian texts as separate families; similarly the Handbook (Munro 1958b, p.110) states "Tail penducle without keels"; Whitley (1962, p.185) has "no caudal keels"; while earlier McCulloch (1922, p.104), recognizing eight Australian genera in the Scombridae, keyed off two of them, *Scomber* and *Gastrochisma* with the entry in the primary couplet "Caudal peduncle without a median keel on each side". On the other hand Günther's diagnosis of *Lepidothynnus* includes "tail with two keels at the base of the dorsal" and Waite states "There are two low ridges on each side of the tail". No keel was found in the Falmouth specimen, *Ls* 372, reported in Part XXV (1979, p.120). In the smaller of the two other specimens, *Ls* 342, there occurs on the left side of the fish a rather deep straight groove, extending for 33 mm from the level of the middle of the 4th dorsal finlet to beyond the base of the 7th finlet by a distance subequal to the base of that finlet (failing to reach level of insertion of upper caudal lobe by some 10 mm): on either side the groove is flanked throughout by an elongate bolster-like elevation, the combined transverse extent of the two bolsters and intervening groove being 10 mm near the middle 7 mm shortly before the rounded ends. No similar structure is apparent on the right side. In the example of *Ls* 460 a short distance below the upper profile a low rounded linear elevation, a ridge rather than a keel, originates below base of last dorsal finlet and runs along the convex extension of the caudal peduncle back beyond the forwardly inserted uppermost and lowermost caudal rays (the forked bases of the rays, as in other scombrids, completely embracing the hypurals the early part of the caudal thus becoming part of the dorsal and anal profiles to about midway between the origin of the uppermost ray and the hind border of the peduncle); a similar ridge occurs below, in this case forming the actual profile of the fish: these ridges, between which is a shallow trough, are traceable for a distance subequal to half postorbital length of head, diverging somewhat posteriorly. Collette & Chao (1975, p.576) state "The Gasterochismatimae and the primitive members of the Scombrinae (Scombrini - mackerels and Scomberomorini - Spanish mackerels) lack supporting bony keels and have only external keels on the caudal peduncle"; and recognize a general evolutionary trend in the relative development of keels leading through low segmented keels to a wide flattened plate extending over several vertebrae. The small pits above and below at base of caudal reported by Waite are present here, but assume the form of short transverse notches rather than of pits.

In discussing variation with growth Waite remarked "The presence of a small corselet is not al all foreshadowed in Richardson's figure"; no distinct corselet is apparent in his own figure nor does a corselet receive express mention in his description, though he notes scales "clothe the whole of the body excepting a naked callous area in which lies the pectoral fin". No distinct naked area is found near the pectoral in any specimens. However, there is found in this region a specialized condition of the scales that may possibly represent an adumbration of a corselet. Above and behind the operculum 6-7 rows of scales extend from the dorsal profile to about the first one-fifth of the upper pectoral rays, their general sense being tangential to opercular border at about 30° to anteroposterior exis of fish, their direction marking them off rather sharply from the more steeply inclined rows adjoining them. This condition is most marked in specimen (b), least in (a). In (a) and (b) several scales below the pectoral are larger than immediately adjacent scales.

Aspects of Form

Head, length to vent, standard length. In a loglog plot these three dimensions are significantly collinear on 1 2 3. With lengths expressed as millesimals of standard length the best straight lines for the Museum's specimens of the rectified relation $L = b\ N^k$ are as follows:

Log L = 1.2970 log N + 2.3873; t 36.793*; calculated (measured) lengths 244(242) 599(612) 1 014(1 000).

Log L = 0.2583 log N + 2.4136; t 15.726*; 259(254) 620(652) 1 036(1 000).

Log L = 1.2671 log N + 2.4014; t 36.895*; 252(250) 621(620) 1 014(1 000).

Dorsal Spines

The spines are slender, highly attenuate and flexible distally, and are readily damaged. In the 1979 fish they increase in length to at least 6th = 7th, in the east coast specimen to at least 4th. In the northwest coast fish, in which all spines other than 10th and 12th are measurable, a clear pattern is evident, involving an anterior set A of 9 spines ascendant caudad, with subsets A_1 = {1st - 3rd} and A_2 = {3rd - 9th} and a posterior set of 8 descendant caudad, with subset B_1 = {13th - 17th} and a possible subset B_2 = {10th - 13th; ? 9th - 13th}. In a loglog plot A_1 is linear on {1-3} and A_2 is linear, with a lesser slope, on {3-9}; while with the elements of B taken in reverse order (*i.e.*, numbered cephalad) and thus yielding as for A a positive slope B_1 is linear on {1-5}, with a suggestion from the graphing that B_2 may well be linear on {5-8; ? 5-9} with a slope markedly less than that of B_1 (and of A_1) but subequal to that of A_2. It will be noted A_1 and A_2 exhibit intersection (common element 3rd spine) as also do B_1 and B_2 (13th common); further if the full series of measurements for B_2 were available it might be found 9th is a member of both A and B.

A_1. Log L = 0.7021 log N + 1.5824; t 27.995***; calculated (measured) lengths, *TLs*, 38(38) 62(63) 83(82).

A_2. Log L = 0.2477 log N + 1.7931; t 7.179***; 82(82) 88(86) 93(92) 97(96) 101(99) 104(105) 107(108).

B_1. Log L = 0.9349 log N' + 1.3180; t 32.761***; 21(20) 40(41) 58(57) 76(79) 94(91). With spine lengths in *TLs* units and serial numbers in common logarithms the total area under the graph of A with spines ascendant caudad is 1.7750; if it is assumed the graph for B_2 from 13th spine to 9th is linear, the total area under the graph of B with spines ascendant cephalad is 1.7517, representing with 8 interspine panels in each set 0.222 0.219 per panel, respectively. The panel figure presumably represents in some way an energy output with two measurable factors (length of spine, vector length along anteroposterior axis of fish): in the present case (accepting linearity for B_2) it is seen to be significantly the same in the enantiomorphic expressions of spine development.

General Form

The broadly fusiform beautifully streamlined form of the Scombridae (*sensu latissimo*, as recognized by Greenwood *et al.* (1966), comprising fishes commonly distributed in Australian texts among half a dozen families) has long been recognized as a remarkable adaptation to fast swimming. That the overall configuration evolved is an efficient one is clear from its constancy — an inspection of the figures in the Handbook

(Munro 1958b) makes it evident that for a score of species there referred to Thunnidae, Scomberidae, Scomberomoridae, Sardidae the general outline of any one species, with allowance made in some instances for some difference in depth, could serve tolerably well for all. In passing mention may be made of the interesting physiological adaptation for rapid and sustained locomotion by the development of homoeothermal mechanisms.

The ontogeny of *Gasterochisma melampus* proceeds from the juvenile with high spinous dorsal, low soft dorsal, short pectoral and exceptionally large ventral fin (this last clearly a specialized adaptation to a specific lifemode) to the more typically scombrid adult through the fin changes considered, and in large part quantified, above. Features in this species (and in general in other scombrids) conducive to speedy movement through water include: dorsal and ventral verticals (Gregory 1928) in or nearly in line and subequal, tending to promote equivalence of stream flow above and below the fish; curvature in the vicinity of highest and lowest points on profiles (apex and gasterion) slight, rendering transition from entrance to run gradual, minimizing turbulence; smooth mainly scaleless head compressed, with dorsal surface forming a lancet arch surmounted by a fine median ridge for ready entrance, the ventral surface is similarly rather acutely rounded each mandible bounded by a ridge comparable with that of the dorsum, these ridges diverging posteriorly, being for the greater part of the length subparallel to the general plane of the lateral surface of the head; short caudal peduncle specially modified to facilitate even flow by the presence of a stout scaled fleshy pad into which the bases of the rays fit, covering the hypural plate — a condition well illustrated by the radiograph of the caudal complex in a bonito, *Orcynopsis unicolor* (St Hilaire, 1817) by Collette & Chao (1975, fig.57); large furcate caudal fin; reduced falciform or subtriangular ventrals, leading edge evenly convex (large size in young nullified by total reception as occasion arises into the abdominal groove): similarly formed anal and second dorsal; first dorsal here (in adult) low, depressible into a groove (where more highly developed with leading edge highest, sloping markedly backward); caudal keels (inconstant) that may mediate slipstream; dorsal and anal finlets (found also in the allied Gempylidae, and either present as discrete structures or adumbrated by a tuft-like extension of one or two posterior rays of the vertical fins in some carangids; both speedy types); finlets are further considered below.

Dorsal and ventral profiles. - In view of the interest attached to the outline in lateral aspect, 10 equidistant measurements of the height of the dorsal profile above and 10 of the depth of the ventral profile below a horizontal axis between mouth cleft and middle of caudal peduncle have been made for specimen (a) and a polynomial calculated for each of these and for total height of fish represented by their sum. As pointed out by Snedecor (1950, p.392) at the stage of the third degree the polynomial begins to exhibit "certain snakelike curves", appropriate in a context such as the present, and while a formulation at this or even an earlier stage may yield a value of R of 0.9 or better, continued calculation not only results in a general refinement in accuracy but in particular leads to improvement in the estimates of the first and last members of the series of measurements. The relevant data for specimen (a) with 4° equations, N being the serial number of the measurement (counted caudad) and dimensions being millesimals of standard length, are subjoined.

Dorsal profile. $H = 35.72 + 25.154\ N + 1.8481\ N^2 - 0.95286\ N^3 + 0.0493585\ N^4$; R 0.9946; calculated (measured) heights 61.8(61.4) 86.6(87.7) 106.1(108.2) 117.6(115.5) 119.4(114.0) 111.3(111.1) 94.1(102.3) 69.5(70.2) 41.0(35.1) 12.8(14.6).

Ventral profile. $D = 71.99 + 13.49\ N + 13.2377\ N^2 - 3.21399\ N^3 + 0.1702648\ N^4$; R 0.9869; 95.7(90.6) 129.9(140.4) 158.6(156.4) 175.3(171.7) 175.1(169.6) 155.9(155.0) 121.5(131.6) 87.0(85.0) 39.8(35.1) 19.3(14.6).

Total vertical extension. $H + D = 92.18 + 61.252\ N + 5.6933\ N^2 - 2.7343\ N^3 + 0.1483542\ N^4$; R 0.9947; 156.5(152.0) 218.0(228.1) 265.9(264.6) 291.3(286.6) 291.7(283.6) 266.3(266.1) 218.2(233.9) 152.2(155.2) 84.6(70.2) 23.2(29.4).

To illustrate the improvement of prediction in the caudal region gained by taking the calculation one degree further, the data for the 5° equation for the dorsal profile are here noted for comparison with the data for the 4° recorded above.

H = 11.05 + 102.25 N - 38.6226 N^2 + 8.09505 N^3 - 0.8499830 N^4 + 0.0327033 N^5; R 0.9982; calculated heights (measured, as above) 59.9 91.2 106.8 113.9 117.5 113.3 97.6 69.8 36.3 14.7.

Width. Measurements of the width of the same individual at 10 equal intervals between snout tip and hypural have been made and a 4° polynomial calculated.

W = 49.53 + 22.723 N - 0.9445 N^2 - 0.50725 N^3 + 0.035460 N^4; R 0.9938; calculated (measured) depths, *TLs*, 70.8(70.9) 87.7(88.2) 98.4(97.1) 101.9(101.5) 98.7(100.6) 88.3 (88.2) 73.5(70.6) 56.4(58.8) 40.3(39.7) 29.7(29.7).

Relation of width and depth. When these 10 measurements of width are plotted against the 10 measurements of total depth at the same points along the anteroposterior axis an interesting relation becomes apparent. For measurements 1-5 at the front and 9-10 at the posterior part of the fish the relationship is highly significantly linear R + 0.996 (z 3.057), the slope being 0.281 the intercept 22.53 (all dimensions *TLs*). The three measurements 6 7 8 in which the coordinates of depth lie below the line (in a downwardly concave arc) are those at the level of the second dorsal and anal — which, with the retractile first dorsal and anal withdrawn and the pectorals folded, present the only local interruptions to the general curve, a circumstance that may well account for the lapse in this region from the linear width-depth relation subsisting throughout the rest of the length.

Finlets

As suggested above the develoment of finlets in such fast and powerful swimmers as the scombrids is probably to be seen as a locomotory adaptation. These structures are found to present interesting relations in respect of (1) location relative to whole fish (2) location within the series (3) shape (4) size that may be presumed to have hydrodynamic significance, though in just what fashion at present remains undetermined. These aspects have been made the subject of general investigation, with quantitative data reported for specimen (c).

(1) Location relation to whole fish. The development of finlets along the profiles behind the soft dorsal and anal fins (placed about opposite) and in advance of the caudal would seem to relate to the mediation of the stream flow above the stream bed in the latter part of its emergent phase behind the point of maximum resistance (in the example here examined the greatest height of the dorsal profile the greatest depth of the ventral profile and the greatest width is in each case found at the 4th of the 10 measurements taken at equal intervals along the primary fish axis), presumably operating towards the maintenance, after the localized friction occasioned by the vertical fins, of an effective fair form (*i.e.*, one bounded by surfaces of continuous curvature), with the contour not too abruptly decreased by the pronounced peduncular decrement in body volume.

(2) Location within the series. At the next level downward in spatial arrangement, the location of the members of the series relative to one another, a systematic pattern is recognizable. With the anterior point of insertion of the hindmost finlet taken as origin and successive distances back to the insertions of the earlier finlets measured it is found the seven lengths are a function of their reverse (*i.e.*, cephalad) serial number, N', with $L = b\,N'^{(k)}$. For the dorsal finlets the rectified equation has slope 0.9943 intercept 1.0391 with calculated (measured) lengths, *TLs*, 32(32) 64(62) 95(98) 127(132) 159(161) 190(192) 221(211); the anal series has slope 0.9660 intercept 1.4883 lengths 31(30) 61(61) 89(92) 117(120) 146(148) 174(175) 202(193). For the first equation t is 50.578*** for the second 33.538***.

(3) Shape. The shape undergoes systematic change along the series, the anterior finlets being subquadrangular, with successive members backward developing a progressively lengthening pennon, the total length of the hindmost finlet being about thrice that of the first and about thrice that of its own base. These pennons (which find obvious analogues in the dorsal, particularly the second dorsal, and anal fins of some sharks) are mobile (the best developed highly so) and may be presumed to mediate filaments of flow.

As here developed the tip of the last finlet extends back to make contact with the base of the rigid anterior caudal ray, about which it plays freely. Hence during differential displacement of the caudal fin and the precaudal region the finlets' mobility can be assumed to promote continuity of flow between the two components of the current bed.

(4) Size. The systematic change in form is associated with a regular increase in length from first finlet to last; in a loglog plot the lengths being linear on reverse serial numbers,

Dorsal. Log $L = -0.4722 \log N' + 1.8413$; t 48.353***; calculated (measured) lengths, *TLs*, 26.0(25.7) 27.8(28.7) 29.8(29.8) 32.5(32.5) 36.1(35.1) 41.3(40.9) 50.2(50.0) 69.4 (70.2).

Ventral. Log $L = -0.4323 \log N' + 1.8148$; t 31.151***; 26.6(26.3) 28.2(28.7) 30.1(30.7) 32.6(32.5) 35.9(34.8) 40.6(39.5) 48.4(50.3) 65.3(64.9

The finlets increase in height to the 4th then decrease to the 8th. In both the dorsal and anal sets there is apparent some tendency for the heights in the ascendant set to be an exponential function of the serial numbers and the heights in the descendant set of the reverse serial numbers, but the relations in these small sets do not all reach statistical significance (dorsal t 7.178*3.015 anal 7.376*4.904). The height, however, calls for further consideration. The fact that as in both the height and the depth of the body above and below the primary horizontal axis the maximum here is attained also at about the middle of the length suggests the possible existence of a recognizable relation between the contours of the body and of the finlets; this possibility has been investigated as follows. The scale of distances between the bases of the finlets specified above has been proportionally transferred to the longitudinal extension considered for the body profile (*i.e.*, *Ls*) and the heights and depths at the relevant levels calculated from the polynomials for the dorsal and ventral profiles of the fish given above, and against these have been graphed finlet heights. A striking result emerges, the two types of contour being strongly correlated, dorsal body with dorsal finlets ventral body with anal finlets, each pair with markedly different anterior and posterior segments. With dorsal finlets 1-4 we find r 0.997 (z 3.299) with 4-8 (the segments intersecting) r 0.995 (z 3.230); with anal finlets r 0.991 (z 3.225) r 0.972 (z 2.124). With the relation expressed as a linear equation $y = mx + c$, for dorsal finlets 1-4 m = 0.064 c = 6.605 t = 23.673**, for 4-8 m = 0.029 c = 11.223 t = 17.658**: for anal finlets 1-4 0.043 6.916 10.245**, for 4-8 0.023 11.469 7.141*.

As with the superior and inferior profiles of the body, the total curves constituted by the external margins of the dorsal and anal finlets are adequately specified by polynomials of the third degree. Equations for specimen (a) below.

Dorsal finlets. $H = -0.118 + 8.23\,N - 1.444\,N^2 + 0.07475\,N^3$, R 0.9953; calculated heights, *TLs*, 6.7 11.2 13.6 14.5 14.3 13.4 12.4 11.6.

Anal finlets. $H = 0.501 + 8.161\,N - 1.3823\,N^2 + 0.06743\,N^3$; R 0.9898; 8.0 11.8 14.4 15.3 15.2 14.3 13.0 11.8.

The investigations here reported are clearly of an exploratory nature only; examination of more extensive sets of data is necessary before definitive conclusions can be reached. However, the high degree of precision of the relations encountered suggests these interesting and novel formulations may well specify morphometric patterns with significant biological and hydrodynamic implications not at present apparent.

Coloration

No mention of color occurs in the diagnosis by Richardson (1845) of the generic characters of *Gasterochisma melampus* ("nomen genericum fissuram ventris denotat"), while in his account of *Lepidothynnus huttonii* Günther (1889) observed merely, "Colour uniform steel-grey, lighter below; cuadal fin and inside of pectoral darker". Waite reported body nearly black above and silvery beneath, head steel-blue. "Midnight blue above lilac to gunmetal on sides and greyish silvery below" (Whitley 1962); Whitley gives "blueskin" as an alternative vernacular name to the customary butterfly mackerel.

Among our material specimens (a) and (c) are much alike, with trunk and tail very deep blue in parts approaching black down to near midlateral line, thereafter gunmetal lightening below to silvery and becoming close to white immediately above ventral profile; (b) differs noticeably, being overall much lighter and in general more bluish. Dorsum of head blackish, darkest anteriorly. Operculum in (a) (c) dark greyish narrowly bordered with off-white, in (b) much lighter and with wider more yellowish border, in all with indications of 2-3 oblique lighter stripes, obscurely yellowish or in (b) distinctly reddish. Preoperculum more or less like trunk but with some yellowish. Small yellowish arcs regularly present bordering eye in front and behind. Lower jaw in (a) partly yellowish partly whitish with some dusky marbling inferiorly, in (b) pale yellow virtually immaculate, in (c) blackish brown in front obscurely yellow behind with some black mottling. First dorsal hyaline, "like plastic" (Whitley 1962), spines sometimes whitish or straw (brown, Waite). Second dorsal and anal similar, dark brownish in parts close to black, tips of some rays ashen or pale yellowish. Pectoral with rays brownish or deep grey, almost black on inner surface (fin silvery, Waite). Ventral black (bluish black, Whitley) except for first ray which shows some brownish red and white mottling (front ray silvery, Whitley), in (b) short orange streaks on bases of 3 rays. Caudal with outer rays blackish others greyish or whitish, on lower lobe of (b) on both lobes of (c) heavily mottled dark and light (tail black, Waite).

Family PLEURONECTIDAE

Ten species of right-hand flounder have so far been reported at one time or another from Tasmanian waters, of which individual authors have recognized half a dozen or fewer: a further species is now added. These are listed below and the status accorded them in some selected texts noted. In the subjoined schedule the presence of a cross indicates Tasmanian occurrence, that of a number signifies the species concerned has been expressly treated by the author as synonymic with the species listed with that number in the left-hand column; doubtful entries are shown with a question mark, placed after the specifications (locality or taxonomic status) that is queried. Questions of synonymy are the subject of comment only by Norman (1926) McCulloch (1929) Last (1978).

	Johnston 1883,1891	Lord 1923,1927	Lord & Scott 1924	Norman 1926	McCulloch 1929	Munro 1957	Last 1978	Scott herein
1 *Ammotretis lituratus* (Richardson, 1843)	x?	-	-	-	x	-	x	x
2 *Ammotretis rostratus* Günther, 1862	x	x	x	x	x	x	x	x
3 *Ammotretis tudori* McCulloch, 1914	-	x	x	x1?	x	x	1	-
4 *Ammotretis macrolepis* McCulloch, 1914	-	x	x	x3?	x	x	x	x
5 *Ammotretis elongatus* McCulloch, 1914	-	-	-	-	-	-	-	x
6 *Rhombosolea plebeia* Richardson, 1843	-	-	-	x?	-	x?	-	-
7 *Rhombosolea monopus* Günther, 1862	x	-	-	6	6	-	8?	-
8 *Rhombosolea tapirina* Günther, 1863	x	x	x	x	x	-	x	x
9 *Rhombosolea flesoides* Günther, 1863	-	x	x	8	8	-	8?	-
10 *Azygopus pinnifasciatus* Norman, 1926	-	-	-	x	-	x	x	x
11 *Taratretis derwentensis* Last, 1978	-	-	-	-	-	-	x	x

With Tasmania interpreted as including Bass Strait, it is or is included among the type localities of seven species: 1 [no locality (collected by Thomas James Lempriere 1796-1852, public official, author, artist, Hobart) = Tasmania, *fide* McCulloch (1929, p.281)]; 2 ["Norfolk Is." = Tasmania (McCulloch)] 3, 4, 8, 10, 11. The generic name *Ammotretis* is regularly rendered *Amnotretis* in the early Tasmanian catalogues by Johnston.

Observations on Some Tasmanian Fishes: Part XXVII

The seven species of left-hand flounder validly included in the Tasmanian faunal list have been keyed in Part XXI (1975).

Genus *AMMOTRETIS* Günther, 1862

Ammotretis Günther, 1862, CAT. FISH. BRIT. MUS., 4, p.458. Type-species, *Ammotretis rostratus* Günther.

Ammotretis elongatus McCulloch, 1914

Ammotretis elongatus McCulloch, 1914, p.123, pl.27. Type locality: "Investigator Strait, South Australia, or the area south of Kangaroo Island".
Ammotretis elongatus: Waite, 1921, p.159, fig.260 and 1923, p.183, unnumbered fig.: Norman, 1926, p.271: McCulloch, 1929, p.281: Scott, 1962, p.90, unnumbered fig.: Scott, Glover & Southcott, 1974, p.103, unnumbered fig.: Whitley, 1964, p.49.

Identification

Ammotretis elongatus is readily distinguishable from the six remaining species accepted as Tasmanian by Last by the following combination of characteris: snout produced into a fleshy hook, two pelvic fins the right with 13 rays, joined to anal, no fleshy tubercle at tip of first ray of left pectoral, depth of body >2 (2.1-2.5) in length without caudal fin. In the key by Last (1978, p.22) it enters the last couplet, being distinguishable from the two species there included, *A. lituratus* and *A. macrolepis* by its greater number of right pelvic rays, 13 (*cf.* 10-12), higher pelvic ratio, >3 (*cf.* 1.5-2.4); further from the first species by lacking a fleshy tubercle on the left pectoral and from the second by having decidedly fewer rays along the lateral line, 66 (*cf.* 88-92).

Material

A specimen 65 mm in standard length 76 mm in total length, collected by Mr J. Shea at Goose Island, Bass Strait in May 1980 (Q.V.M. Reg. No. 1980/5/64).

Meristic Characters

D. 75. A. 55. P. dex. 11 P. sin. 8 V. dex. 13. V. sin. 5. C. 3/12/3. Scales in longitudinal series just above lateral line *ca* 90, between lateral line and highest point on dorsal profile *ca* 30.

Dimensions

The species was founded (McCulloch 1914) on a single individual 98 mm long and the account in the report on the Heterosomata collected by the *Endeavour* (Norman 1926) is based on three specimens 90-125 mm in total length. Neither author provided any absolute morphometric data, such dimensions as are noted being given in the form of proportions. All dimensions here recorded are thousandths of standard length 65 mm. Measurements are in general taken between parallels, those taken point-to-point being shown in parentheses.

Total length 1200. Head 285, length to preopercular border 200. Snout to lower eye 83, to upper eye 89. Lower eye diameter horizontal 65, vertical 34, diameter of eyeball horizontal 31, vertical 26, shortest direct distance to ventral profile 60; greatest external diameter of orbit 71. Upper eye diameter horizontal 62, vertical 37, diameter of eyeball horizontal 32, vertical 28; greatest external diameter of orbit 71. Interorbital 14. Length of maxillary (80), length of lower jaw of ocular side (83), of blind side (85). Snout to vent 285 (323). Left pectoral length to origin 286, total length of fin 91, length of longest (5th) ray 85, oblique length of base (28). Right pectoral length to origin 292, total length of fin 135, length of longest (6th) ray 123, oblique length of base (37). Left pelvic length to origin 197, length of base 63(64), length of longest (5th) ray 63. Right pelvic length to origin *ca* 70 (some displacement of body here), length of base 300(323), length of longest (11th = 12th) ray 77. Dorsal length to origin 0 to termination 977, length of longest ray (near middle of fin) 112 of last ray 29. Anal length to origin 315 to termination 980, length of longest ray (near middle of fin) 108 of last ray 29. Length of longest (inner) unbranched caudal ray 137, of

longest (middle) branched 185. Depth at front of eye 262 back of eye 323 operculum 477, maximum depth (at about 0.4 of standard length) 492, depth of caudal peduncle 108.

General Features

Elongate, evenly ovate, its depth 2.03 in standard length, *Ls*, (McCulloch, 2¼ in *Ls* Norman, 2⅛-2½ "in the length"), depth of caudal peduncle 2.7 in head. Head 3.51 in *Ls* (McC., 4¾ in *Ls*, N., 4-4⅜ "in the length"). Snout moderate, to anterior eye 3.4 in head; rostral hook stout, its inferior border strongly concave, its length subequal to width of hook, acute, barely extending down to level of maxillary on ocular side. Lower eye slightly in advance of upper, horizontal diameter of latter 1.7 its vertical diameter, 4.4 interorbital (N., about 4), 4.6 (McC., 4⅞-5, N., 4¾-5) in head, 0.7 of relevant preocular length. Mouth small, the two sides not symmetrical; on blind side the dentigerous jaws much alike but upper upwardly-convex, a trifle longer than lower, which is upwardly concave; maxillary failing to reach level of eye by about one-fifth eye length; length of lower jaw of ocular side 3.4 (N., 3⅞-3¾) in length of head. Several minute tubercles on lower lip on ocular side (N., "forming a fringe"). Teeth along whole length of both jaws on blind side, small closely set moderately acute, in a band of subequal width throughout, in 5-6 rows. Nostrils shortly in front of eyes small tubular with very slightly raised rims, anterior larger (McC., on "both sides with posterior lobes"). Upper angle of gill slit about level with inferior orbital border of upper eye, opercular lobe just above pectoral base. Gill rakers minute tubercular (N., about 10) on upper limb of anterior arch. Scales variable; on ocular side mostly cyloid, those behind and below the head either with 2-4 blunt or jagged processes or with 4-6 short tolerably acute processes inserted inside the scale border; those on blind side in general ctenoid with 8-10 slender acute processes with a bifid base and behind these a segment of blunt elevations; extending up dorsal rays, other than some anterior ones, anal and caudal rays for two-thirds of their length or more; not present on pectorals or pelvics. Lateral line almost straight from caudal peduncle to just behind level of pectoral tip where it turns a little upward in a very slightly upwardly convex segment to just above angle of gill slit, then continuing briefly (McC., continuation not shown in figure) in a nearly straight line halfway towards upper eye.

Dorsal 75 (McC., 74-75, N., 74-75) commencing at tip of rostral hook, about 30 (McC., figure, 20) anterior rays more or less free simple slender minutely serrated, forming a crest, the hindmost ray somewhat higher than the more massive ray immediately following it, these later rays briefly bifid, longest 2.5 in head; last ray inserted far back on caudal peduncle almost contiguous with uppermost caudal ray. Anal 55 (McC., 50-51 N., 50-51), in general similar to dorsal but a trifle lower than its postcephalic portion, commencing shortly behind (McC., figure, below) pectoral base, ending barely behind dorsal. Right pectoral 11 (N., 8-10), upper end of its base about level with middle of lower eye, 1.8 in head. Left pectoral 8 (N., no count; McC., overall pectoral range "P. 8-10"), length 0.7 that of (N., equal to) right. Right pelvic 13 (McC., N., 13), its anterior ray at the tip of the isthmus, inserted below jaws of blind side, its base a little longer than head, in line with and joined to anal, posterior rays scaly on ocular side. Left pelvic 5 (McC., N., 3-4), 3 rays close together, the first of these located about as noted by Norman, opposite space between eleventh and twelfth of right pelvic, the 2 others in advance of these separated from them and from each other by almost as great an interval as that between third and fifth rays, total base 4.6 in head. Caudal 3/12/3, rounded, 1.4 in head. Caudal peduncle very short, last dorsal and anal rays almost contiguous with first caudal rays, depth 2.7 in head length.

Where the scales have been lost the pterygiophores form a conspicuous closely set palisade the intervals between them much less than their width, the combined height of the dorsal and ventral series accounting for one-fourth of the depth at opercular border, for rather more near middle of length; the external termination shows a bulbous enlargement, with a suggestion the radial may be briefly bisegmented (or trisegmented), but this point cannot be satisfactorily determined.

Aspects of Form

It has been shown in these contributions that for a wide range of species in a loglog plot length of head length to vent and standard length are effectively collinear on three low natural numbers (modally 1 2 3). While this formulation is appropriate for the majority of forms in which the vent is normally located shortly in advance of a reasonable rearward anal fin, it is clearly not applicable to species with an exceptionally forwardly placed vent. In one such species, *Paratrachichthys trailli* (Hutton, 1876), in which the vent lies between the bases of the ventral fins, it is found (see above) that, with logarithmic values as before, a significant straight line is obtained with a reverse pattern of graphing involving a negative slope with standard length on 1 and the other lengths on higher natural numbers in the vicinity of 10 (in this instance 9 10). However, it was questioned whether such a formulation was a biologically significant one or a mathematically neat but adventitious solution. It is thus of interest to note that in the present species as represented by our specimen such a solution with abscissal values of 1 9 10 is statistically significant.

Log L = —0.5410 log N + 3.0002; t 67.547**; calculated (measured) lengths, *TLs*, 288(285) 305(308) 1 000(1 000).

The above results have prompted the examination of another form with the vent close behind the head noted in these contributions, *Carpus rendahli* Whitley, 1941, measurements of a Tasmanian example of which recorded in Part XXIV (1978) yield the subjoined equation, the abscissae here being 1 8 10.

Log L = -0.9895 log N + 3.0013; t 44.049*; calculated (measured) lengths, *TLs*, 103(100) 128(132) 1 003(1 000).

An equation for the low, even curve of the dorsal profile with greatest rate of change of curvature one-tenth, that should not be without comparative taxonomic significance has been computed (displacement in the region forward of the operculum precluded a satisfactory evaluation of the ventral profile). Ten measurements of height of profile, H, above a line joining most advanced point on rostral hook and middle of end of caudal peduncle were made.

$H = 138.93 + 22.877\ N + 7.11001\ N^2 - 2.25042\ N^3 + 0.125175\ N^4$; R 0.9991; calculated (measured) heights, *TLs*, 167(162) 207(203) 221(226) 233(231) 228(222) 208(202) 176(180) 137(142) 101(103) 80(77).

Coloration

After preservation in alcohol both sides are in general more or less uniformly yellowish, blind side the lighter. McCulloch and Normal mention and the former figures minute black dots over the head, body and fins on ocular side: in our pecimen a sprinkling of obscure black dots occurs on the head but only a few are evident on body and fins, the latter overall white. The location of internal organs is indicated by a dark oval patch behind the head above the vent and a pennon-like area beginning immediately behind this and extending just above the ventral pterygiophores back to within about half a head length of caudal origin; also the course of the vertebral column can be traced.

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CLAYS AND BRICKS OF THE PENAL SETTLEMENTS AT PORT ARTHUR AND MARIA ISLAND, TASMANIA

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(with four tables, one text-figure and two plates)

ABSTRACT

HUTTON, J.T., 1981 (30 ix): Clays and bricks of the penal settlements at Port Arthur and Maria Island, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 153-161 (with one figure and two plates). ISSN 0080-4703. C.S.I.R.O. Division of Soils, Glen Osmond, South Australia.

The making of clay bricks was a major industrial activity at the penal settlements of Port Arthur and Maria Island. The silicate minerals in the clays used were mainly illite and kaolin as is usual in brickmaking. All bricks examined had more than 1.2% K_2O and so the surface clay at the Port Arthur settlement, which is montmorillonitic and low in potassium, was not used. Many of the bricks made at Port Arthur are soft due to underfiring and unaltered clay minerals have been detected in some.

Much of the brickwork of the ruins at Port Arthur has disintegrated due to the lack of strength in the bricks and due to the presence of more than 1% salt, mainly NaCl, which, as the result of exposure to rain, wind and sun, has crystallized near exposed surfaces. Bricks, collected from inside a continuously occupied building and thus not exposed to any source of salt or water, were sound but contained 1 - 2% salt. As the salt is similar in composition to that of seawater, it is concluded that at least some of the bricks were made from clay that had been puddled with seawater.

An old photograph of the Penitentiary with its roof still intact and hence taken before the 1898 bushfires shows deterioration of the exposed bricks at that early date. It would appear that a large number of the bricks manufactured at Port Arthur during occupation of the settlement were of such inferior quality that they could not be expected to last for centuries.

INTRODUCTION

At a Workshop on Building Materials Conservation held in Hobart during April 1975, Cripps and Spratt (1977) reported that the deterioration of many of the buildings at the penal settlement at Port Arthur could be attributed largely to two factors; firstly to the badly made and underfired bricks which contain soluble salts and secondly to water movement which conveyed the salts through the masonry. At exposed surfaces, where evaporation takes place, salts are left behind and erode the bricks as crystallisation proceeds (Pla e 1). In 1979 Crawford, de Bavay and Cripps, Architects, in association with Fowler, England and Newton, engineers, submitted a detailed report entitled "To Conserve Port Arthur" to the Director, Tasmanian National Parks and Wildlife Service. This report gives the results of the extensive research initiated by them into many aspects of the conservation of the ruins at Port Arthur.

A documentary search (Glover 1978) into the history of Port Arthur showed that brick manufacture was a major industrial activity with 68 300 bricks being manufactured in March 1834, 160 700 bricks in December 1841 and an average of 14 000 per month during the decade 1858 to 1869. Besides their use in the large number of buildings erected at Port Arthur, the bricks were exported to Hobart and possibly to other centres. From 1830 until 1845, most of the bricks were made south of the settlement on the southwestern shore of Carnarvon Bay using clay from nearby shallow pits. After 1845, brickmaking was transferred to a site on the hill beyond the church, locally known as Brickfields Hill.

Clays and Bricks at Port Arthur and Maria Island

PLATE 1.- Recent view of southern wall of Penitentiary. (Photograph by courtesy Tasmanian Film Corporation).

During inspections at Port Arthur and Maria Island by the Tasmanian Restoration Advisory Committee, the author, a member, collected samples of bricks and clays for laboratory examination.

In June 1975, Dr. N.K. Roberts, University of Tasmania, was engaged by Messrs Crawford, de Bavay and Cripps to undertake some investigations into the decay of bricks and sandstone from Port Arthur and his results are included in the report "To Conserve Port Arthur" (V. Sup.). Surfaces of some of the bricks from the Penitentiary were examined under a JEOL scanning electron microscope and the salt efflorescence was found to be crystals of sylvite (KCl) (Roberts and Kallend 1976).

SAMPLES AND METHODS OF ANALYSES

Five samples of clay were collected from Port Arthur area during visits by the committee, and in addition, the Tasmanian Department of Mines kindly made available samples taken during a detailed clay survey of the area by Threader (1976). Figure 1 shows the location of the Tasmanian Department of Mines' bores, the other clay sampling sites, and the boundaries of the main geological formations as mapped by Cromer (1976). From Maria Island, two samples of clay were collected from the shallow clay pits one km east of Darlington near the arched kilns. In all, eleven bricks have been sampled, five from Port Arthur and six from Maria Island. Two bricks from Port Arthur, brick 1 (red) and brick 2 (white), were collected from under the floor of the Roman Catholic Chaplain's cottage which is one of the buildings that has been almost continuously occupied since the early days of the settlement. Brick 3 was taken about 2 m above ground level from the northeastern corner of the Penitentiary at Port Arthur.

The soluble salts present in the bricks 1, 2 and 3 were extracted with water from the finely-crushed bricks and the respective solutions absorbed onto cellulose powder. The wet cellulose was then dried, ground and pressed into suitable discs for analysis by XRF methods such as those described by Norrish and Hutton (1977) for the analysis of plant tissue.

The analysis of the clays and bricks for major elements was also made by XRF methods in this case using the fusion technique of Norrish and Hutton (1969) and applying their inter-element correction factors.

The minerals present in the fine fraction (< 2 μm) of the clay samples were identified by a combination of X-ray diffraction methods and additional chemical tests (Norrish and Pickering 1977).

RESULTS

Several samples were analysed from each of the cores taken by the Tasmanian Department of Mines and the results have been averaged for each bore hole. The results given in table 1 have been restricted to five major elements and to five minerals. Details of the chemical analysis of the bricks are not presented here but the ratios of silicon, potassium and titanium to aluminium together with the same ratios for some of the clay samples are given in table 2. Table 3 gives the ionic analysis of the salts extracted from bricks 1, 2 and 3 from Port Arthur and from three of the clay samples (A, G and J). The ratios of the chloride, potassium, magnesium and calcium ions to sodium are given in table 4 and similar data for rainwater, groundwater and seawater are included. (Full details of the results are available on request to Chief, CSIRO Division of Soils, Glen Osmond, Sth Australia 5064).

DISCUSSION

Cromer (1976) described three major rock units near the penal settlement at Port Arthur, namely Permian marine pebbly mudstone and sandstone, Triassic non-marine sandstone and mudstone and Jurassic dolerite which has intruded both groups of sedimentry rocks. The results given in table 1 show that the composition of the clay deposits is related to these rock types. In particular the potassium content varies from less than 1.0% K_2O for clays on dolerite to more than 3.0% for clays on the marine sediments. Montmorillonite and kaolin are the dominant clay minerals in the material weathered from dolerite and both illite and quartz are absent. In the clays derived from the sediments, illite and kaolin are the dominant minerals and quartz was detected in four of the seven samples. The small amounts of montmorillonite in the samples of clays on the non-marine Triassic sediments at Brickfields Hill could possibly be derived from the dolerite which is mapped within 30 m of the sample sites.

The colour of bricks is largely due to the iron oxide content and as seen in table 1 there is very considerable variation in the amount of iron in the clays associated with the two sediments and thus from either of these clays it was possible to manufacture white, red or attractively mixed red and white bricks.

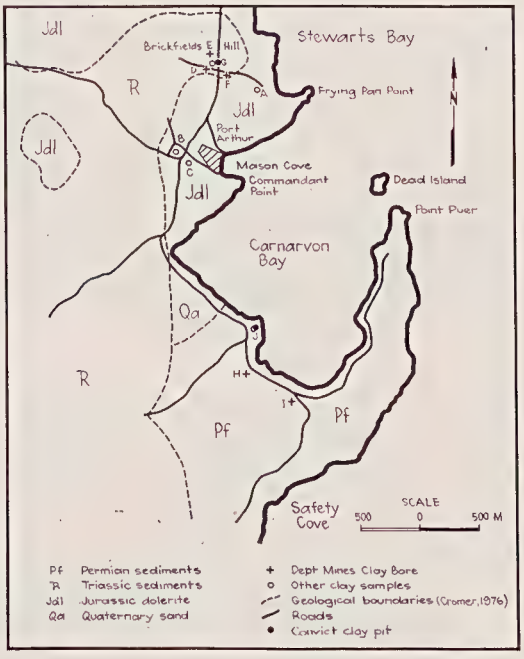

FIG. 1- Location of clay sampling sites at Port Arthur.

Dr W.F. Cole, CSIRO Division of Building Research, Highett, Victoria, (*pers. comm.*, 1974) has estimated the firing temperature of two Port Arthur bricks he examined to be between 800° and 850°C, at least 200°C below the optimum for the clay used. At temperatures above 1000°C, illite and kaolin, which are phyllosilicate clay minerals with hydroxyl ions in their crystal lattice, are irreversibly changed to minerals of other structures. If, however, the temperature does not exceed 700-800°C, the phyllosilicate structure is not fully destroyed and some of the

TABLE 1

CLAYS FROM PORT ARTHUR

Underlying geological formation	Jurassic dolerite			Triassic sandstone & mudstone				Permian sandstone & mudstone		
Location and bore number	500m W of Frying Pan Point	Near R.C. Chaplain's cottage	Near model prison	Bore 2	Bore 7	Bore 5	Brick-fields Hill	Bore 8	Bore 9	N face shallow pit southwest Carnarvon Bay
Sample identification	A	B	C	D	E	F	G	H	I	J
Depth, m	1.0-1.5	0-0.5	0-0.5	3.7-5.5	3.7-4.6	0-7.0	0-0.5	0.9-1.8	0-0.9	0.5-1.0
Chemical analysis, %:										
Fe_2O_3	14.7	7.7	15.6	5.4	1.2	7.7	0.9	0.9	2.6	5.0
TiO_2	0.82	0.89	1.08	0.99	0.79	0.75	0.90	0.49	0.83	0.74
K_2O	0.80	0.68	0.26	1.74	2.51	2.74	2.52	2.85	3.07	3.58
SiO_2	47.5	64.1	49.4	51.5	68.5	63.3	62.2	70.1	59.3	60.5
Al_2O_3	21.6	14.9	21.8	23.6	19.0	16.9	24.0	17.5	23.3	19.0
Loss on ignition	12.4	10.2	12.8	14.7	7.3	7.8	9.3	5.5	9.5	7.1
Particle size <2µm, %		58	64	30	53	42		50	75	
Mineralogical analysis of <2µm fraction, %:										
Quartz							10	15	5	10
Kaolin	80	20	80	80	30	5	25	55	60	40
Illite				5	70	75	60	25	35	50
Montmorillonite	5	80	10	15		20	5			
Feldspar	15							5		

clay mineral may be reconstituted by the slow incorporation of water and hydroxyl ions (Grim 1962). This appears to be taking place in some bricks at Port Arthur and the presence, in the centre of one brick from the southwestern wall of the Penitentiary, of considerable unaltered illite and kaolin (identified by sharp X-ray diffraction peaks) suggests that parts of some bricks did not reach 400°C.

TABLE 2

RATIO OF ELEMENTS SILICON, POTASSIUM AND TITANIUM TO ALUMINIUM

MATERIAL	SAMPLE	Si/Al	K/Al	Ti/Al
	Port Arthur			
Clays on dolerite	A	1.9	0.058	0.043
	B	3.8	0.072	0.068
	C	2.0	0.019	0.056
	(mean values)	2.6	0.050	0.056
Clays on sediments	Port Arthur			
	D	1.9	0.12	0.048
	E	3.2	0.21	0.047
	F	3.3	0.25	0.050
	G	2.3	0.16	0.043
	H	3.5	0.26	0.032
	I	2.3	0.21	0.040
	J	2.8	0.30	0.044
	(mean values)	2.8	0.22	0.043
Clays on sediments	Maria Island			
	O	5.1	0.19	0.064
	P	5.8	0.21	0.065
	(mean values)	5.5	0.20	0.065
Bricks	Port Arthur			
	1	3.0	0.11	0.041
	2	4.2	0.22	0.053
	3	3.8	0.20	0.052
	4	4.0	0.12	0.043
	5	3.1	0.14	0.044
	(mean values)	3.6	0.16	0.047
	Maria Island			
	6	6.5	0.23	0.069
	7	8.1	0.22	0.083
	8	5.2	0.31	0.057
	9	7.3	0.21	0.071
	10	8.9	0.22	0.088
	11	7.4	0.30	0.067
	(mean values)	7.3	0.25	0.072

Although the structure of the clay minerals is lost during the manufacture of adequately fired bricks, most chemical elements present in the original clay deposit are retained. For example, the potassium content of all the bricks examined from Port Arthur is above 1.2% K_2O and thus clays from within the settlement and derived from dolerite and with an average of 0.7% K_2O (on ignited basis) have not been used exclusively for the bricks manufactured there. For practical reasons, clays developed on dolerite are not suitable for brick making as they contain montmorillonite. This clay mineral requires considerable water to make it sufficiently plastic to be moulded into shape and then on drying, before firing, extensive shrinkage occurs. Illitic and kaolinitic clays are widely used for brickmaking and the early brickmakers at Port Arthur must have carefully sought suitable clays which, unlike the surface clays within the settlement, are situated below a coarser-textured surface soil. For a better comparison of the chemistry of clays with that of bricks, it is more satisfactory to compare ratios of elements rather than absolute values. For example, the data in table 2 show clearly the

marked difference between the K/Al ratio for the clays derived from dolerite and those of all other samples. The element titanium is usually retained during the surface weathering of a rock (Hutton 1977) and is not lost during the firing of a brick so that it can be a useful element in relating clays and bricks. From table 2 it can be seen that the Ti/Al ratios of the two samples of clay and the six bricks from Maria Island are all above 0.056 whereas all samples of bricks and brickmaking clays from Port Arthur have a Ti/Al ratio below 0.054. The difference between the clays and bricks from the two settlements is more pronounced in the Si/Al ratio. All samples from Maria Island have a Si/Al ratio above 5.0 and all from Port Arthur have a ratio below 4.3. The data available are limited but it would appear that there are significant differences in the chemistry of the samples from the two penal settlements and that this could be used to identify the source of clays and/or bricks in these two places and possibly others.

TABLE 3

COMPOSITION OF SOLUBLE SALTS IN CLAYS AND BRICKS (g/kg)

SAMPLE	Na	Mg	K	Ca	Cl	SO_4	Total (from conductivity)
Clay A on dolerite	0.66	0.03	0.03	0.04	0.72	0.2	2.5
Clay J on sediments	0.03	0.04	0.02	0.03	0.03	0.08	0.2
Clay G from Brickfields Hill	0.06	0.01	0.1	0.04	0.14	0.1	0.4
Brick 3 from Penitentiary	7.3	0.35	0.56	1.9	14	0.2	26
Red brick 1 from R.C. Chaplain's cottage	2.6	0.04	0.26	0.2	3.0	0.3	9
White brick 2 from R.C. Chaplain's cottage	2.6	0.6	0.35	1.6	6.7	0.1	13.8

During an on-site examination of the salt content of bricks at Port Arthur (July 1976) by using about 1 g crushed brick, 5 ml water and a simple portable conductivity meter, it was found that 12 bricks had less than 0.1% soluble salts, another 12 had between 0.1% and 1% salts and the majority (26) had more than 1%. Some of the bricks were from walls of roofless buildings situated near the sea, others were from ruins on high ground and some were from a roofed building that has been occupied since erection in 1836 and situated at least 20 m above sea level. Many bricks from under the floor of this latter building, some on the ground and some on timber joists, were tested and found to be in the highest salt category. The salts from two of these bricks and a third from the Penitentiary have been analysed and the results are given in table 3 together with data on the salts in three of the clay samples. The results have been summarised in table 4 and again expressed as ratios, in this case of the chloride, potassium, magnesium and calcium ions to the sodium ion. For comparison, the same ratios for seawater, a sample of groundwater from near the church at Port Arthur and rainwater collected within 15 km of the coast of Victoria (Hutton and Leslie 1958) have been included. The Cl/Na, K/Na, and Mg/Na, ratios are similar to those of seawater and not to the local groundwater and this chemical similarity suggests that seawater had been used during the fabrication of some of the bricks. Seawater contains about 3.5% salts and if in order to puddle the clay to mould the "green" bricks, seawater was added in the ratio of 1 : 3 or 1 : 2 (water : clay), this would yield 1 - 2% salts in the finished brick. Both sodium chloride and potassium chloride melt at about 800°C and do not appear to be significantly volatile at this temperature. As many of the bricks have not been heated above 850°C, most of the added seasalt has been retained. Roberts and Kallend (1976) also concluded from the salt glaze on some of the bricks that seawater was used, at least on some occasions.

Alternatively it has been suggested that the bricks, after incorporation into the walls, have absorbed salts from the rain. A photograph taken before the bushfires of January 1898 shows that some of the bricks in the west wall of the bakehouse and near the top of the tall chimney had at that date already disintegrated to some extent (Plate 2).

PLATE 2.- Early view of north-west corner of Penitentiary. (Photograph from Port Arthur Collection, National Parks and Wildlife Service).

TABLE 4

IONIC RATIOS OF SALTS IN BRICKS, ETC.

	Cl/Na	K/Na	Mg/Na	Ca/Na
Bricks (av. of 1, 2 & 3)	1.22	0.060	0.19	0.37
Rainwater[1]	1.06	0.025	0.24	0.13
Groundwater[2]	0.67	0.030	0.94	0.80
Sea Water	1.16	0.021	0.24	0.04
Clays (av. of A, G & J)	0.96	0.46	0.99	0.66

[1] Data for Cape Bridgewater, Warrnambool & Heywood, Victoria (Hutton and Leslie 1958)

[2] Dr N.K. Roberts. (In report "To conserve Port Arthur", Crawford, de Bavay and Cripps 1979) (V. Sup.).

Thus after 45 years of exposure to sun and rain but protected to some extent by the overhanging roof, the bricks in this west wall were crumbling due to lack of strength and the action of salt. The bricks near the base of the wall could have absorbed salts from the groundwater (seawater) but for those close to the roof the most probable external source is the rain. Salt in the rain is largely derived from the ocean waves breaking near the shore during periods of strong winds, usually from the west or southwest and so the exposed west wall might receive more salt than other areas. Hutton (1976) has shown that the average salt content of the rain is related to the distance from the ocean by the expression NaCl (mg/L) = (58 ÷ $\sqrt[4]{d}$) - 13.5 where d is distance in km from the ocean. As Port Arthur is about 12 km northeast of Storm Bay, the rain, on the average throughout the year, can be expected to contain about 18 mg NaCl per litre. Spratt, in the report "To Conserve Port Arthur" (V. Sup.), has shown that the Port Arthur bricks absorb about 160 g water per kg and thus a dry brick weighing about 3 kg will take in about 8.6 mg NaCl if saturated with rain. If the bricks were not dry they would absorb less and if saturated they will lose some salt by surface run-off. The disintegrating bricks in the west wall of the Penitentiary before the bushfires of 1898 probably contained 40 to 60 g salt per 3 kg brick (the average salt content of a disintegrating brick) and so to obtain this in 45 years from the rain it would be necessary for the brick to dry out completely and then absorb the rain 100 to 150 times per year. It is doubted if this is possible.

Although the salts extracted from the three bricks have Cl/Na, K/Na and Mg/Na ratios similar to those of seawater, the salts that crystallise in a given part of a wall may range widely in composition. Due to the porosity of the bricks, evaporation may take place within the bricks as well as on their surfaces. As the volume of the solution becomes smaller due to evaporation, the liquid will fill only the finer pores within the brick and eventually the sodium and chloride ions, which form the bulk of the dissolved species, will crystallise out as halite (NaCl). The growth of these halite crystals within the fine pores of the brick will produce the pressure to cause disintegration, particularly if the brick is not hard burnt. Eventually as more water and halite are lost the solution will become saturated in respect of other salts. The occasional addition of rain may or may not dissolve some of the halite crystals but will delay the crystallisation of the other compounds. The solution may even be washed away from the surface of the bricks by excess rain or, at the other extreme, during periods of excess evaporation or if the brick is dried in the laboratory, a wide range of salts may appear on the surface. Indeed Roberts and Kallend (1976) have demonstrated the presence of crystals of sylvite (KCl) on the surface of a brick from the northeastern part of the Penitentiary and to explain the sylvite they ascribe the soluble potassium to the action of ion exchange in the brick. This seems unlikely as the value they use for exchangeable potassium, 4.6.m.equiv./100 g brick, is ten times the value of 0.44 m. equiv./100 g reported by Graley and Nicholls (1979) as the median value for the surface 0-10 cm of 13 yellow podzolic soils on mudstone. These soils are similar to those near the clay pits at Port Arthur and the clay minerals present in these yellow podzolic soils are illite and kaolin, the same as in the Port Arthur clays on the sedimentary rocks (table 1). Although exchangeable potassium may have contributed, there are other sources of soluble potassium that might be significant in the bricks. For example, the destruction of the illite clay mineral structure during the firing of the bricks may have released some of the potassium normally considered to be insoluble, the ash of the timber used to fire the kilns contained both potassium and calcium salts and as shown in table 3 the original clay may have contributed about 1/3 of the soluble potassium in the final bricks. The potassium from these sources would remain soluble if the bricks were not heated above 800°C, i.e. high enough to melt potassium chloride and possibly form a glass.

The disintegration of the bricks at Port Arthur is not a recent event. There is little doubt that most of the bricks were underfired and that movement of water in and out soon caused them to decay due to the salts present. The composition of the salts in some bricks strongly suggests that seawater was used for the puddling of clay and that the introduced salts remained essentially unaltered during the low temperature firing. The loss of the roofing of the buildings during the bushfires since the closure of the settlement may have accelerated the disintegration but Plate 2 shows some obvious rotting of the bricks in the west wall of the Penitentiary before the loss of its roof.

The quality of the bricks made at Port Arthur no doubt varied greatly. It appears to have deteriorated markedly towards the close of the settlement for Hunter (1876), reporting on the bricks brought up from Port Arthur for the building of the gaol at Cascades, wrote "and they are of such a wretched and worthless description that I cannot consent to their being used for any building purpose."

A detailed knowledge of the materials used in the buildings of the penal settlements of Port Arthur and Maria Island is essential before sound decisions can be made regarding their preservation or possible restoration. The high salt content, the high porosity and low strength in the bricks create unique problems at Port Arthur.

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OBSERVATIONS ON THE FRESHWATER FISH OF A SMALL TASMANIAN COASTAL STREAM

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(with three tables and one text figure)

ABSTRACT

LAKE, P.S. and FULTON, W., 1981 (30 ix): Observations on the freshwater fish of a small Tasmanian coastal stream. *Pap. Proc. R. Soc. Tasm.*, 115, 163-172 (with one figure). ISSN 0080-4703. Department of Zoology, Monash University, Clayton, Victoria and Inland Fisheries Commission, Hobart, Tasmania, Australia.

Fish were collected on two occasions, May and December 1976, by electro-fishing from Parsons Bay Creek, a small coastal stream in southeastern Tasmania. From the six sites sampled, seven species of native fish and one species of introduced fish (*Salmo trutta*) were collected. In terms of biomass, the short-finned eel *Anguilla australis* dominated the catch, while in terms of numbers *Galaxias maculatus* dominated the catch in May and *Galaxias truttaceus* in December. Trout abundance and biomass were low. The numerical density and the biomass density of fish increased in a downstream direction as did the number of species per site. Standing crop estimates in Parsons Bay Creek indicate that the stream harbours a relatively high standing crop of fish, up to 30.36 g/m^2.

INTRODUCTION

In the published work on Australian freshwater fish there have been only a few reports on the ecology of fish communities in any freshwater body. Few data are available on the relative abundance and biomass of constituent fish species in Australian freshwater fish communities. The aim of this investigation is to examine how the distribution of fish, their population density and their standing crop change in a small Tasmanian stream from source to mouth.

The stream examined has the distinct attraction to fish biologists in that it harbours substantial populations of native fish and only a small population of one exotic fish species (*Salmo trutta*).

Parsons Bay Creek (Figure 1)

This small stream is on the western side of Tasman Peninsula in southeastern Tasmania. From its source (320 m a.s.l.) on the northwestern slopes of Mt Arthur the stream flows in a northwesterly direction to enter the sea at Parsons Bay (147°47'E, 43°08'S) near the village of Nubeena. Most of the catchment of the stream is covered by wet sclerophyll forest with some of the slopes and valley floor cleared for unimproved pasture. Part of the valley floor of the lower half of the stream is occupied by apple and pear orchards. The top part of the catchment (Stations 1 and 2) lies on Triassic sandstones while the major part of the catchment lies on Jurassic dolerites.

The creek has two major tributaries, an unnamed creek which rises on Benjafields Ridge and Thompsons Hill and flows north to enter Parsons Bay Creek near Highcroft and Plummers Creek which rises on the slopes of Mount Clark and Mount Koonya and flows southwesterly to join Parsons Bay Creek near Noyes Hill. The first tributary being of equal size to Parsons Bay Creek changes the stream order from 1 to 2. Following the stream order system of Horton (1945) as modified by Strahler (1957), Parsons Bay Creek at its mouth is thus an Order 2 stream. The catchment of the creek has a dendritic drainage pattern. The mainstream has a length of 12.6 km and a drainage area of 36 km^2.

The pH of the stream is about 7.20 and the conductivity about 270 uS/cm. Thus the stream has a higher conductivity and hence level of total dissolved solids than the

majority of lotic waters examined in Tasmania (Buckney and Tyler 1973).

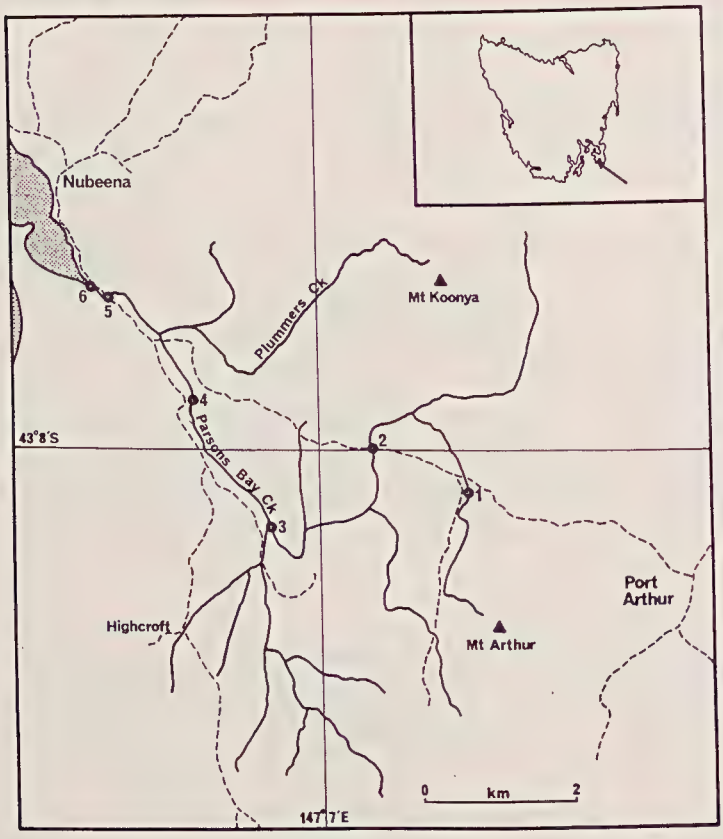

FIG.1.- Locality Map.

Sampling Sites

Site 1. This site is 2.4 km from the source of the creek on the slopes of Mt Arthur. The stream at this site emerges from an area of swamp. The stream is in a narrow channel flowing over a yellow clay substratum and it is lined with reeds. The length of the site that was fished was 80 m with a mean width of 0.5 m (area = 40 m^2) and a uniform depth of about 0.30 m. The site is on cleared land at an altitude of 260 m (a.s.l.).

Site 2.- This is 5.2 km from the source at an elevation of about 130 m (a.s.l.). just upstream of the second crossing (from Port Arthur end) of the stream by the Port Arthur-Nubeena Road. The length of the stream fished was 70 m with a mean width of 2.3 m (area = 161 m^2). The depth varied from 15 to 50 cm. The substratum of this site was mostly large stones and pebbles and the stream is relatively fast flowing. The top 40 metres of the site are completely shaded by eucalypts and tea tree while the lower section is open.

Site 3.- This site at an altitude of about 80 m a.s.l. is 7.6 km from the creek's source. It is situated just upstream of the junction between Parsons Bay Creek and the unnamed major tributary. The length of the section fished was 65 m with a mean width of 3.1 m (area = 201.5 m^2). The depth varies from about 0.20 m to 0.75 m. The upper part of this site, in a downstream direction, consists of a shallow pool, a riffle and a flat while below this part there is a cascade section over protruding dolerite bed rock.

Site 4.- This site is in a small densely vegetated gorge at an altitude of about 40 m (a.s.l.) and 9.5 km from the source. The section of stream fished was 70 metres long with a mean width of 3 m (surface area = 210 m). The stream is fast flowing over and around large boulders and stones. This site is almost totally shaded by a dense bank-side growth of tea tree, willows, eucalypts and blackwood. The depth of the site varies from about 0.20 to 0.80.

Site 5,- This site was straddled by the bridge of the fourth crossing of the stream by the Nubeena-Port Arthur Road. It is 0.3 km upstream from site 6 and is 12.3 km from the creek's source, and is at an altitude of 3 m a.s.l. The section of stream fished was 52 m with a mean width of 3.75 m (surface area = 195 m^2). The upstream part consists of flats and a pool while below there is an extensive stickle section. This section is

shaded only beneath the bridge. The depth varied from about 0.15 m to 0.80 m.

Site 6.- This site is just above sea level and just above the entry of the creek into the sea. The section of stream fished was 50 m with a mean width of 4.1 m (area fished = 205 m^2). Approximately 20 m of the section, although fresh water, is under tidal influence. On both sampling occasions the section was electro-fished at low tide. The depth varied from 0.10 to 0.60 m. The site was partly shaded by scattered eucalypts and casuarinas.

Sampling Methods

The six sites on the stream were sampled on two separate occasions; in late autumn (1-2 May 1976) and late spring (4-5 December 1976). On both occasions the creek was at the same level. The electro-fishing apparatus used was constructed from a design of Dr R.H.K. Man (pers. comm.) of the Freshwater Biological Association, U.K., with the design of the control switch circuitry being modified. Electric power was provided by a Honda E 800 U generator and the A.C. current was rectified to a 50 p.p.s. D.C. current. Each stream section was delineated by upstream and downstream 1 cm mesh nets. The section was then electro-fished twice in an upstream direction with a time interval of 30 minutes between each run. All fish captured were identified, counted and their wet weights and lengths recorded in the field.

In order to assess the efficiency of the electro-fishing procedures in Parsons Bay Creek, a series of five electro-fishing runs were carried out at Site 5 in December 1976. A time interval of 30 minutes elapsed between each successive electro-fishing run.

RESULTS

In the five electro-fishing runs at Site 2 in December 1976, six species of native fish and one species of exotic fish (*Salmo trutta*) were caught. The numbers of fish for all species caught per electro-fishing run were plotted against previous total catch and the line fitted by eye (Southwood 1966). In two electro-fishing runs in Parsons Bay Creek with the apparatus used, 60.2 per cent of the estimated total catch was caught. A non-parametric contingency test (Elliott 1971) revealed that for the seven species of fish caught at Site 2 the proportion of fish of each species caught per successive run did not vary significantly ($P < 0.05$).

When wet weight of all species caught per successive electro-fishing run was plotted against previous total biomass the estimated total biomass was 4 510 g and 77.2 per cent of the total estimated biomass was caught in the first two electro-fishing runs. The non-parametric contingency test revealed that for the seven species of fish the proportion of biomass of each species caught per successive electro-fishing runs did vary markedly.

Estimates of the total population of fish in the sections of Parsons Bay Creek that were electrofished were approximated by multiplying the observed catch in two successive electro-fishing runs by 1.661. Less reliable estimates of the total biomass of fish were made by multiplying the biomass of the observed catch in two successive electro-fishing runs by 1.295.

Seven species of native fish *Anguilla australis* (Richardson), *Galaxias maculatus* (Jenyns), *Galaxias truttaceus* (Valenciennes), *Pseudaphritis urvillii* (Cuvier and Valenciennes), *Favonigobius tamarensis* (Johnston), *Retropinna tasmanica* McCulloch and *Geotria australis* (Gray) and one species of exotic fish (*Salmo trutta* Linnaeus) were collected from Parsons Bay Creek in May 1976.

The short-finned eel *Anguilla australis* was the dominant fish by weight (53.5 per cent of the total biomass collected) and *Galaxias maculatus* was the numerically dominant fish in the system (51.62 per cent of the total number of fish collected) (table 1). Of the eight species caught in the creek three species (*Pseudaphritis urvillii*, *Favonigobius tamarensis*, *Retropinna tasmanica*) were caught only at site 6, close to the sea. On the

TABLE 1

The estimated numerical densities (No./m^2) (A) and biomass densities (g wet weight/m^2) (B) of fish at each sampling site in Parsons Bay Creek on 1-2 May 1976

	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	A	B	A	B	A	B	A	B	A	B	A	B
Anguilla australis	0.15	2.07	0.02	2.83	0.10	6.83	0.07	3.13	0.20	7.98	0.05	1.62
Galaxias maculatus	-	-	-	-	0.11	0.31	0.03	0.08	0.68	2.00	0.50	.72
Galaxias truttaceus	-	-	0.03	0.05	0.05	0.31	0.15	2.73	0.14	2.36	0.03	0.31
Pseudaphritis urvillii	-	-	-	-	-	-	-	-	-	-	0.02	1.88
Favonigobius tamarensis	-	-	-	-	-	-	-	-	-	-	0.19	0.20
Retropinna tasmanica	-	-	-	-	-	-	-	-	-	-	0.03	0.01
Geotria australis	-	-	-	-	-	-	0.02	0.01	0.03	0.02	-	-
Salmo trutta	-	-	0.03	0.42	0.02	3.19	0.01	0.12	0.01	4.32	-	-
Total numerical density	0.15	-	0.08	-	0.28	-	0.28	-	1.06	-	0.82	-
Total biomass density	-	2.07	-	3.75	-	10.64	-	6.07	-	16.68	-	4.74

TABLE 2

The estimated numerical densities (No./m^2) (A) and biomass densities (g wet weight/m^2) (B) of fish at each sampling site in Parsons Bay Creek on 4-5 December, 1976

	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	A	B	A	B	A	B	A	B	A	B	A	B
Anguilla australis	0.04	1.07	0.22	11.36	0.42	18.00	0.12	14.50	0.50	15.19	0.98	23.01
Galaxias maculatus	-	-	-	-	0.21	1.18	0.04	0.23	0.62	2.36	0.61	2.53
Galaxias truttaceus	-	-	0.05	1.02	0.12	1.66	0.06	1.27	1.70	2.66	0.85	2.66
Pseudaphritis urvillii	-	-	-	-	-	-	-	-	0.02	0.13	0.26	1.37
Favonigobius tamarensis	-	-	-	-	-	-	-	-	-	-	0.65	0.71
Rhombosolea tapirina	-	-	-	-	-	-	-	-	-	-	0.05	0.08
Geotria australis	-	-	-	-	-	-	-	-	0.26	0.09	-	-
Salmo trutta	-	-	-	-	0.02	2.98	0.01	1.58	0.02	2.60	-	-
Galaxias brevipinnis	-	-	-	-	-	-	0.02	0.01	-	-	-	-
Total numerical density	0.04		0.27		0.77		0.25		3.12		3.4	
Total biomass density		1.07		12.38		23.82		17.59		23.03		30.36

other hand, *Anguilla australis* occurred at all sites, being the only species present at site 1 and being the dominant fish by weight at all sites except site 6. The only exotic fish collected, *Salmo trutta*, was poorly represented.

In terms of estimated numerical density of fish and estimated biomass density of fish, site 5 yielded the highest numerical density and highest biomass density, while site 2 had the lowest estimated numerical density and site 1 the lowest estimated biomass density (table 1).

In December 1976, eight species of native fish and one species of exotic fish were collected with the two native fish species (*Galaxias brevipinnis* Günther and *Rhombosolea tapirina* Günther), being additions to the species caught in May. As in May the short-finned eel dominated the catch in terms of biomass while *Galaxias truttaceus* dominated the catch numerically (table 2).

The Tamar River goby *Favonigobius tamarensis* and juvenile greenback flounder *Rhombosolea tapirina* were only found at site 6 and surprisingly in view of their distribution in May, ammocoete larvae of *Geotria australis* were only found at site 5. *Galaxias brevipinnis*, allowing for only two electro-fishing runs per site, was only found at site 4 but at site 5 this species was collected in the fifth electro-fishing run.

In May 1976 eight species of fish were caught in the creek while in December 1976 nine species of fish were caught. On both sampling occasions the number of species increased steadily from source to mouth with *Anguilla australis* at both times being the only species at site 1 (tables 1 and 2).

In both May and December sites 5 and 6 harboured species found nowhere else. Thus in May *Pseudaphritis urvillii*, *Favonigobius tamarensis* and *Retropinna tasmanica* were only found at site 6 and in December *Favonigobius tamarensis* and *Rhombosolea tapirina* were only found at site 6. Ammocoete larvae of *Goetria australis* were collected at sites 4 and 5 in May but only at site 5 in December. The smelt *Retropinna tasmanica* was only collected in May while *Rhombosolea tapirina* and *Galaxias brevipinnis* were only collected in December 1976.

For both sampling occasions the estimated numerical density and the estimated biomass density increased from source to mouth (tables 1 and 2). In December the estimated numerical density and the estimated biomass density of fish at each site were greater than in May. The increase in numerical density was most marked at sites 5 and 6 and was largely due to a great increase in the number of *Anguilla australis*, *Galaxias truttaceus*, *Favonigobius tamarensis* and *Pseudaphritis urvillii* at these two sites. Increased numbers of *Anguilla australis* were also caught in December at sites 2 and 3. The increased biomass density of the December samples compared with those of the May samples was largely due to the considerable increase in the biomass of eels captures at all sites except site 1 in December.

DISCUSSION

For reliable estimates of numbers and of biomass of fish in the stream it is important to have an estimate of the efficiency of the electro-fishing apparatus that is used. It was found in Parsons Bay Creek, using our electro-fishing apparatus that in two successive electro-fishing runs 60.2 per cent of estimated total number of fish and 77.2 per cent of the estimated total biomass of fish in any one section were caught. Such results compare favourably with efficiencies reported by other workers electro-fishing in systems similar to that of the study (e.g. Burnet 1952, Nicholls 1958b, Hopkins 1970, Fletcher 1979).

The numberical proportion of fish caught in each successive electro-fishing run for each species was shown not to vary significantly, but the biomass proportion of fish caught for electro-fishing run for each species did vary significantly. The principal cause for this variation appeared to be due to the heavier catches of eels and trout in

the initial runs due to the fact that large fish are more susceptible to capture by electro-fishing than smaller fish (Vibert 1967, Lagler 1971). Hence in the first and second runs through a stream section, the large fish are more likely to be captured.

In Tasmania, at present, there are 25 recorded species of native freshwater fish (Frankenberg 1974, Andrews 1976, Fulton 1979, McDowall 1980) and six species of introduced freshwater fish (Lake 1978, McDowall 1980). From Parsons Bay Creek seven species out of the 25 freshwater fish native to Tasmania were collected and one out of the six species of introduced freshwater fish. The Tamar River goby *Favonigobius tamarensis* and the greenback flounder *Rhombosolea tapirina* in Parsons Bay Creek may be regarded as being marine fish capable of living in fresh water though neither species is listed by Frankenberg (1974) in his list B "Species of predominantly marine families occasionally recorded in fresh water".

The short-finned *Anguilla australis* was found at all sites in both May and December and in terms of fiomass, eels were dominant at all sites except site.6 in May. Very little scientific data are available on the biology of eels in Tasmania. Short-finned eels are widespread in Tasmania occurring in almost all of the coastal rivers of the State, in both fast and slow flowing sections (Fulton 1979). In Tasmania, as in New Zealand (*vide* Cairns 1950), short-finned eels have three distinct migrations in their life history (Frankenberg 1974). The first migration, the movement into the estuaries of glass eels appear to occur in winter and early spring (Fulton 1979). The upstream migration of the elvers in the streams appear to take place in mid-summer (Sloane 1978b, Fulton 1979). A downstream spawning migration of the adult eels must occur but details of the time are not available. Frankenberg (1974) suggested that this migration occurs in autumn. In Parsons Bay Creek very few small eels or elvers were collected at any of the sites in May but in December elvers were abundant at sites 5 and 6 suggesting that in December that the upstream migration of elvers was under way.

Galaxias truttaceus was numerically dominant in the creek in December with a large number of juvenile fish at site 5. The fish was distributed throughout Parsons Bay Creek except at the top, e.g. site 1. The adult fish appear to favour sections of stream with large rocks, turbulent flow and a complete plant canopy. This species of galaxiid is widely distributed in Tasmania (Frankenberg 1974, Andrews 1976). *G. truttaceus* is a constituent of Tasmanian whitebait runs with a migration of juvenile fish occurring from September to December (Scott 1941, Lynch 1965, Fulton 1979, McDowall 1980). The timing of this migration fits with the observation at sites 5 and 6 of a large number of juvenile fish in December.

Galaxias maculatus was limited to the lower and middle sections of Parsons Bay Creek and was the numerically dominant fish in May. It was well represented in both May and December at both sites 5 and 6, with a high proportion of juvenile fish at these sites, in both months. This fish is common in coastal streams of Tasmania and is generally confined to the lower reaches of these streams (Frankenberg 1974, Andrews 1976, McDowall 1980). In this study the species penetrated about 5.5 km up the stream from the sea (total length of the stream was about 12.6 km). There are two major migrations in the life cycle of *G. maculatus* (McDowall 1978). In Tasmania the peak of *G. maculatus* occurrence in the whitebait run is reached in September and October (Scott 1938, Fulton 1979). At both sites 5 and 6, at both sampling times, juvenile fish were abundant. The juveniles in December may have resulted from the whitebait run in September-October.

The sandy or freshwater flathead, *Pseudaphritis urvillii* was found in the lower reaches of Parsons Bay Creek at Sites 5 and 6. In May adult fish were collected at site 6 while in December at sites 5 and 6 a lot of small fish were present. Hortle (1978) investigated the ecology of this fish in Nicholls Rivulet, a small stream in southern Tasmania. He found that this fish penetrated upstream for a considerable distance to near the source of the stream; a distribution quite different from that found in Parsons Bay Creek. The densities of *Pseudaphritis urvillii* in Nicholls Rivulet were much higher (e.g. up to 17 fish/m^2) than those found for this fish in Parsons Bay Creek (max. density = 0.16 fish/m^2 at site 6 in December). The latter low density of *P. urvillii* is

comparable with densities for this fish reported in southern Tasmanian streams by Sloane (1978a).

In this study *P. urvillii* was found in areas with a coarse gravel and stone bottom especially around logs and aquatic macrophytes. This observation fits with the habitat description given for this fish by Hortle (1978). Hortle (1978) found that density of *P. urvillii* decreased in an upstream direction and that this decline in density was paralleled by an increase in the age of the fish. Young fish (0+) were to be found in the lower reaches of the stream under estuarine influence. Hortle (1978) suggested that *P. urvillii* bred in the estuaries and that the young 0+ fish migrated into the lower reaches of the stream under estuarine influence in December-January. This observation accords with the presence of small *P. urvillii* at site 6 in December.

The Tamar River goby *Favonigobius tamarensis* was only found at site 6 in both May and December. The fish was listed by Whitley (1964), Lake (1971) and McDowall (1980) as a native freshwater fish but not as such by Frankenberg (1974) or Lake (1978). At site 6 this species was most abundant in the rocky stickle section just above tidal influence.

The young greenback flounders *Rhombosolea tapirina* are invaders from the sea being found in fresh water at site 6 just above tidal invluence. Flounders of the genus *Rhombosolea* appear to have a propensity to enter fresh water for in New Zealand two species, *Rhombosolea retiaria* and *R. leporina*, are found in fresh water - in coastal rivers and lakes (McDowall 1978). McDowall (1980) does not however list any species of the family Pleuronectidae as occurring in fresh water in southeastern Australia.

Aspects of the biology of the greenback flounder in Pittwater, a shallow estuarine area near Hobart, were investigated by Kurth (1952). He found that the flounder especially the young fish could tolerate a substantial range of both salinity and temperature but he did not record flounder in fresh water.

Although two species of lamprey (*Mordacia mordax* and *Geotria australis*) are to be found in Tasmanian coastal streams (Frankenberg 1974, Fulton 1979) the ammocoetes of only one species (*Geotria australis* were collected from Parsons Bay Creek. The occurrence of *Geotria australis* in Parsons Bay Creek is at some variance with the suggestion of Hubbs and Potter (1971) that *Geotria australis* does not occur in the rivers of eastern Tasmania. The ammocoete larvae were collected in gravel and sand at the lower sites (sites 5 and 6); not an ideal habitat for ammocoetes according to Hardisty and Potter (1971).

The brown trout (*Salmo trutta*) is an uncommon fish in Parsons Bay Creek occurring in low densities at all sites except Sites 1 and 6. The fishing pressure on this creek appears to be very low and there are no records of liberations of trout into it. The stock of fish in the creek may have been established and be maintained by migratory trout which occur in southern Tasmanian estuaries (Nicholls 1961). Parsons Bay Creek and its tributaries do not possess any substantial sections of stream with clean gravel suitable for trout spawning and thus the resident trout population may have a low recruitment rate. Some recruitment does however occur as indicated by the low numbers of small trout collected.

In Parsons Bay Creek in May and December 1976, both the numerical density and the biomass density of the fish increased in a downstream direction. Both of these trends differ somewhat from trends found by other workers. The density of fish (number of fish per unit surface area of water) has been reported to decrease in a downstream direction (e.g. Thompson and Hunt 1930, Larimore and Smith 1963). The explanation of these trends is that as one proceeds downstream "the individuals are usually larger and the total weight per unit area remains more or less constant" (Hynes 1970). However, examination of the data of other stream workers reveals that these two trends are by no means universal in their application. For example, in a Scottish stream with salmon and trout no trend for fish density to decrease downstream was apparent (Egglishaw 1970). In both the North Esk River and St. Patricks River, northern Tasmania, Nicholls (1958b) found that both numerical and biomass density increased in a downstream direction.

In Parsons Bay Creek, due principally to the dominating influence of the eels, there is no trend for small fish upstream to be replaced in a downstream direction by larger fish of the same or similar species. In the creek the increase of the numerical and biomass densities in a downstream direction may be partly due to the migration into fresh water, on a short-term or long-term basis of fish from the sea (e.g. *Favonigobius tamarensis*, *Anguilla australis*, *Galaxias maculatus*, *Galaxias truttaceus*, *Pseudaphritis urvillii*). The pool of fish in the sea potentially capable of migrating into fresh water nourished in part or wholly by marine resources, could have an important influence on the numbers and standing crop of fish in the sections of stream close to the estuary (sites 5 and 6).

TABLE 3

Estimates of standing crop (g/m^2) of fish in Parsons Bay Creek Compared with estimates of standing crop from some Australian and New Zealand streams

SITE	STANDING CROP, g/m^2		REFERENCE
Parsons Bay Creek, Tasmania	May 1976	December 1976	
Site 1	2.07	1.07	This study
Site 2	3.75	12.38	
Site 3	10.64	23.82	
Site 4	6.07	17.59	
Site 5	16.68	23.03	
Site 6	4.74	30.36	
Tasmania:			
Ration Tree Creek, nr Mole Creek		7.66	Nicholls 1958a
Sassafras Creek, nr Liena		16.42	Nicholls 1958a
North Esk River 1955		.56-17.45	Nicholls 1958b
" " " 1956		1.79-16.80	Nicholls 1958b
St. Patricks River 1955		.34-20.83	Nicholls 1958b
" " " 1956		.11-11.76	Nicholls 1958b
Victoria			
Watchbox Creek, Strathbogie Ranges			
section with *Galaxias olidus* only		1.13-2.71	Fletcher 1979
sections with *Salmo trutta* *Galaxias olidus*		.81-5.53	Fletcher 1979
Running Creek, Kinglake			
sections with *Gadopsis marmoratus* and *Galaxias olidus*		4.14-18.50	Fletcher 1979
sections with *Gadopsis marmoratus*, *Galaxias olidus*, *Salmo trutta*, *Anguilla australis*		3.54-7.27	Fletcher 1979
New South Wales			
MacLaughlin River, Snowy River System		19.04	Lake 1957
Abercrombie River, Lachlan River System		19.38	Lake 1957
New Zealand			
Horokiwi stream		26.54	Allen 1951

As table 3 shows, the standing crop in Parsons Bay Creek varies considerably both in time and from site to site. Site 1 has the lowest standing crop - 1.01 and 2.07 g/m^2 while the highest standing crop of 30.36 g/m^2 is found at site 6 in December. In terms of representative Tasmanian streams (Nicholls 1958a, b), Victorian streams (Fletcher 1979) and N.S.W. streams (Lake 1957), Parsons Bay Creek has a relatively high standing crop (table 3), and is quite comparable in magnitude with the upper levels of standing crops in known, highly productive streams (table 3, and see Hynes 1970).

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RELIC CLINOPYROXENES AND METAMORPHISM OF THE MOTTON SPILITE OF THE LEVEN HILLS DISTRICT, TASMANIA

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(with one table, four text-figures and one plate)

ABSTRACT

HASHIMOTO, M., SAITO, Y. and KASHIMA, N., 1981 (30 ix): Relic clinopyroxenes and metamorphism of the Motton Spilite of the Leven Hills district, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 173-179 (with four figures and one plate). ISSN 0080-4703. National Science Museum, Tokyo and Ehime University, Matsuyama, Japan.

Electron probe analyses of the relic clinopyroxenes and bulk chemical compositions of the Motton Spilite greenstones both suggest that they have been derived from basaltic rocks similar to ocean floor tholeiites. The greenstones are considered to have been affected by low-grade metamorphism whose physical conditions corresponded to those of the lower grade part of the glaucophanitic facies.

INTRODUCTION

The Motton Spilite is a Cambrian volcanic formation in northwestern Tasmania. It consists mainly of basaltic rocks which have been affected by low-grade metamorphism and transformed into greenstones (e.g. Banks 1962; Burns 1964). About twenty specimens of the Motton Spilite in the Leven Hills district to the south of Ulverstone and a few of similar rocks in the Smithton and Kanunnah Bridge, Arthur River, areas were collected. The sample localities are shown in figure 1.

This paper deals briefly with the chemical composition of relic clinopyroxenes preserved in the greenstones and with the low-grade metamorphism by which the rocks have been affected.

ORIGINAL BASALTS

The original rocks of the Motton Spilite are considered to have been basalts, dolerites, trachybasalts and their pyroclastic equivalents, judging from their petrographic characteristics. They are all weakly metamorphosed, but the degree of recrystallization is generally so low that the igneous textures have been well preserved in most of the studied samples. Under the microscope, the rocks show various textures such as porphyritic, doleritic, intergranular, variolitic and amygdaloidal. Glassy mesostases, olivine, plagioclase and iron ore are completely or partly recrystallized into secondary minerals, whereas clinopyroxene has retained its original state.

Relic clinopyroxenes

The clinopyroxenes are pale purple in thin section and not infrequently show hourglass extinction. The pyroxenes of the three selected samples were analysed by means of an electron-probe microanalyser, Hitachi XMA Model 5A, with three channel detecting system and 38° take-off angle. Accelerating voltage and specimen current were 15KV and 0.03 μA, respectively. Synthetic periclase, corundum, quartz, wollastonite and rhodonite and natural albite, adularia, haematite and kaersutite were used as standards. The observed intensity ratios of unknown to standards were corrected by the alpha factor of Albee and Ray (1970). The results listed in table 1 and shown in figure 3 indicate that the analysed clinopyroxenes are augite slightly rich in TiO_2 and Al_2O_3. In some greenstones pyroxenes are mantled at least partly with aegirine-augite (Plate 1(a)) the analysis of which is also given in table 1.

The aegirine-augite is apple green to yellowish green in thin section, while the host

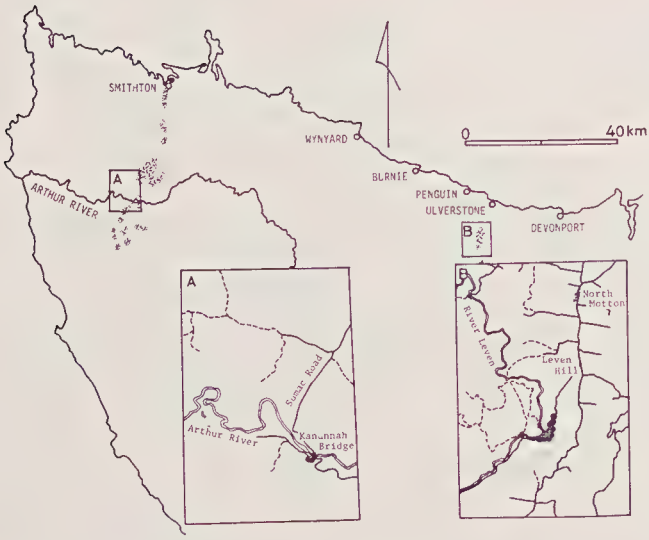

FIG. 1.- Sampling localities. The stippled pattern indicates Cambrian basic volcanic rocks (Williams, 1978). The sampling localities are shown by black dots.

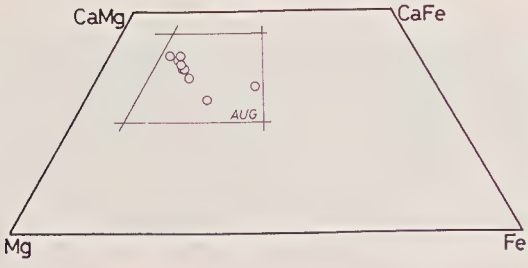

FIG. 2.- Ca/Mg/Fe ratios of relic augites of the Motton Spilite.

augite is almost colourless or very pale brownish yellow. The angle $c \wedge Z$ of the augite is about 40° and $C \wedge X$ of the aegirine-augite is about 38°. The latter pyroxene shows strong optical dispersion and does not entirely extinguish under the crossed nicols. Anomalous interference colours are observed at the rotation positions close to that of extinction. The aegirine-augite mantles of the pyroxenes are so small that further details of optical properties are difficult to determine.

Chemical compositions of augitic pyroxenes of basaltic rocks are considered to vary in relation with the rock series to which their hosts belong. Clinopyroxenes rich in Ti and Al are said to occur generally in rocks of the alkali basalt series, those rich in Si in the tholeiitic series rocks (Kushiro 1960; Le Bas 1962; Maruyama 1976). However Nisbet and Pearce (1977) stated that the chemistry of clinopyroxenes would give only rarely an unambiguous conclusion about their host.

The Si - Al and Ti - Al relations in the analysed relic pyroxenes are illustrated respectively in figures 3a and 3b. All but one of the plots fall, in figure 3a, near the line representing Si + Al = 2.0 for O = 6, and the composition range extends over both fields of the tholeiitic and alkali basaltic clinopyroxenes given by Maruyama (1976). The Ti - Al diagram of figure 3b also shows that the pyroxene compositions of the studied greenstones are intermediate between those of the tholeiites and akali basalts. Consequently, it is concluded from the relic clinopyroxene chemistry that the original rocks of the Motton Spilite greenstones would have been intermediate basalts between tholeiites and alkali basalts. Furthermore, the composition field shown in figure 3b is in the midst of the larger field of the pyroxene analyses of tholeiitic deep-sea basalts given by Schweitzer *et al* (1979).

Bulk chemical composition

No new bulk chemical analysis was made for this study. A few greenstone analyses of the Motton Spilite and the correlatives, however, have been given by Scott (1951, 1952), Spry (1962) and Burns (1964). All the published analyses are basaltic, their SiO_2 contents varying from 47 to 53%. The $(Na_2O + K_2O)$ - SiO_2 and TiO_2 - P_2O_5 plots are shown respectively in figures 4a and 4b. Most of the plots fall in the field of the alkali

TABLE 1

Electron-probe microanalyses and atomic ratios of relic clinopyroxenes of the Motton Spilite greenstones, Leven Hills, Tasmania

SiO_2	51.70	50.21	50.88	51.34	50.57	50.79	50.72	50.41	51.20	50.43
TiO_2	0.55	0.46	0.52	0.56	0.55	0.49	0.66	0.53	0.57	0.12
Al_2O_3	1.81	2.61	2.48	2.60	3.54	2.13	2.18	1.38	2.33	0.36
FeO*	11.48	7.40	8.79	9.33	8.51	9.86	14.83	19.30	10.12	23.23
MnO	0.19	0.16	0.16	0.16	0.16	0.19	0.28	0.69	0.21	0.53
MgO	16.96	17.24	16.40	17.04	16.90	16.67	16.13	12.00	16.70	7.53
CaO	17.77	20.17	19.49	18.94	19.28	18.51	14.81	16.12	18.19	14.98
Na_2O	0.19	0.25	0.23	0.23	0.26	0.25	0.25	0.37	0.25	2.63
K_2O	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.02	0.00	0.04
Number of analyses averaged	1	2	2	2	3	2	1	1	2	2
Si	1.918	1.886	1.908	1.901	1.877	1.911	1.913	1.935	1.912	1.996
Al^{IV}	0.079	0.114	0.092	0.099	0.123	0.089	0.087	0.063	0.088	0.004
Al^{VI}	-	0.001	0.018	0.015	0.031	0.006	0.010	-	0.015	0.013
Ti	0.015	0.013	0.016	0.016	0.016	0.014	0.019	0.015	0.016	0.005
Fe	0.356	0.233	0.275	0.289	0.266	0.310	0.468	0.620	0.316	0.771
Mn	0.006	0.005	0.005	0.004	0.004	0.007	0.009	0.022	0.007	0.017
Mg	0.938	0.967	0.917	0.941	0.935	0.936	0.907	0.687	0.929	0.445
Ca	0.706	0.813	0.782	0.752	0.768	0.746	0.598	0.663	0.727	0.635
Na	0.013	0.018	0.016	0.016	0.018	0.018	0.019	0.027	0.018	0.202
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002

*Total iron as FeO

1 - 9 : augites, 10 : aegirine-augite

basalts in the former diagram (Macdonald and Katsura 1964). On the other hand, in the latter diagram TiO_2 contents are all less than 2.0% and P_2O_5 less than 0.3%. It is suggested, therefore, that the rocks may not be alkali basalts, but are ocean ridge basalts (Rhodes 1973). This discrepancy between the two conclusions taken respectively from the $(Na_2O + K_2O)$ - SiO_2 and TiO_2 - P_2O_5 relations would result from a slight chemical change, particularly in the alkali contents, in the rocks after their formation.

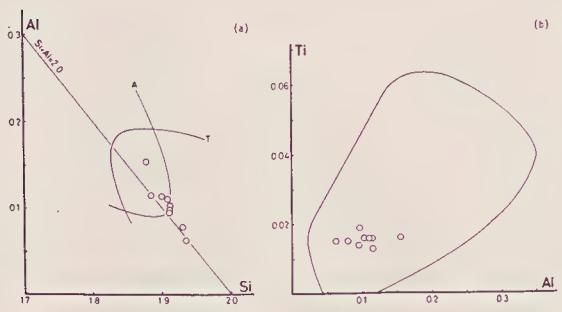

FIG. 3.- Si - Al and Ti - Al relations in relic clinopyroxenes of the Motton Spilite greenstones.
a) Si - Al relation. Curves A and T given by Maruyama (1976) indicate respectively the fields of augitic pyroxenes in the alkali basaltic and tholeiitic rocks.
b) Ti - Al relation. Curve encircles the the composition field of most of clinopyroxenes from deep-sea tholeiites given by Schweitzer *et al.* (1979)

Scott (1951) also gave trace element analyses of four King Island Cambrian basalts. Their Ni contents range from 70 to 453 ppm, and Ti/Cr and Ba/Y ratios are respectively 2.3 - 219 and 0.5 - 33. According to Beccaluva *et al.* (1979), these values suggest that the analysed rocks are similar in trace element geochemistry to ocean floor tholeiites.

In conclusion, the electron-probe analyses of relic clinopyroxenes and the bulk chemical compositions of the Cambrian basaltic rocks in northwestern Tasmania and King Island indicate that the basalts may have been originally tholeiites similar to those of ocean floor. The possible origin as other kinds of tholeiite is, of course, not excluded.

METAMORPHISM

Various metamorphic minerals have been formed in the Motton Spilite greenstones due to the low-grade metamorphism which affected the rocks. They are pumpellyite, epidote, chlorite, albite, quartz, sphene (leucoxene), calcite and sericite.

Pumpellyite is found in various modes of occurrence. It not infrequently replaces relic plagioclase, being in association with albite and/or chlorite (Plate 1(b)). Pumpellyite occurs also in recrystallized mesostases of basalts and in veins and pools. The associated minerals in the veins and pools are chlorite, albite, quartz and epidote, although the last mineral is rather rare in the studied greenstones.

The metamorphic mineral assemblages observed in the Motton Spilite greenstones are thus summarized as follows:-
(a) pumpellyite + chlorite + albite + quartz; (b) pumpellyite + chlorite + albite; (c) pumpellyite + chlorite + quartz; (d) pumpellyite + epidote + chlorite + albite + quartz; (e) pumpellyite + epidote + chlorite + albite; (f) pumpellyite + epidote + chlorite + quartz.
The former three are more common than the latter assemblages. All the assemblages are accompanied by sphene as an accessory. Calcite occurs alone or in association with other minerals in veins. Scattered minute flakes of sericite are often observed in relic plagioclase.

It is noticeable that actinolite occurs neither as a replacing mineral of clinopyroxene nor as an assemblage mineral of the matrix, though Scott (1951) reported its common occurrence in the King Island Cambrian spilites. Furthermore, no prehnite has been found in rocks during the present study.

The metamorphic mineral assemblages described, in conjunction with the absence of actinolite and prehnite and scarcity of epidote, are quite similar to those observed in greenstones of the Chichibu terrain in western Shikoku, Japan. The metamorphic conditions of this terrain are considered to represent the lower grade part of the glaucophanitic Sambagawa belt of southwest Japan (Hashimoto and Kashima 1970; Hashimoto 1972a).

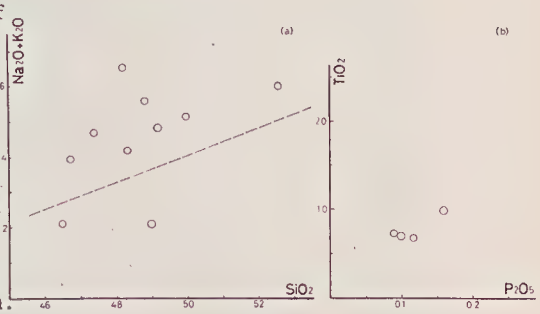

FIG. 4.- Bulk chemical compositions of the Motton Spilite greenstones and their correlatives.
(a) Total alkalies - silica relation. Broken line shows the boundary given by Macdonald and Katsura (1964) separating the fields of tholeiitic and alkali basaltic rocks.
(b) TiO_2 - P_2O_5 plots.

The mineral pumpellyite has rather wide stability range in rocks of basic composition. It is found in association with prehnite in some relatively low-pressure metamorphic rocks exemplified by Triassic volcanogenous rocks in the Tarringatura district, New Zealand (Coombs 1954; Coombs *et al.* 1959), by similar rocks of the Siluro-Ordovician formations in the Lyndhurst district, New South Wales (Smith 1962), and by Miocene volcanogenous rocks of the Tanzawa Mountsins, Japan (Seki *et al.* 1969). On the other hand, the assemblage pumpellyite-actinolite is widely found in basic rocks of lower grade parts of metamorphic regions of the truly high-pressure or high-pressure intermediate types (Hashimoto 1966, 1972b; Miyashiro 1973; Nakajima *et al.* 1977). Furthermore, wide occurrence of pumpellyite-chlorite and pumpellyite-epidote-chlorite associated neither with prehnite nor with actinolite has been reported mostly from terrains which represent further lower grade parts of the high-pressure metamorphic regions such as the glaucophanitic Sambagawa and Sangun belts of southwest Japan (Hashimoto and Kashima 1970; Nishimura 1971; Hashimoto 1972b; Toriumi 1975).

As mentioned earlier, some relic clinopyroxenes in the greenstones are mantled by aegirine-augite (plate 1a and table 1). Similar aegirine-augitization of relic pyroxenes was reported in greenstones of the Chichibu terrain (Toriumi 1975) and is considered to have resulted from the low-temperature and relatively high-pressure metamorphism of the rocks.

Consequently, the metamorphism which affected the Motton Spilite greenstones may have been similar in physical conditions to that of the lower grade part of the Japanese Sambagawa high P/T belt.

ACKNOWLEDGEMENTS

We are highly indebted to Dr Emyr Williams and other geologists of the Tasmanian Department of Mines who were of great help in the field study. Out gratitude is extended to Prof S. Banno and Mr K. Aiba, Department of Geology, Kanazawa University for their kind help in the electron-probe analysis of pyroxenes. A review by Dr E. Williams improved the manuscript.

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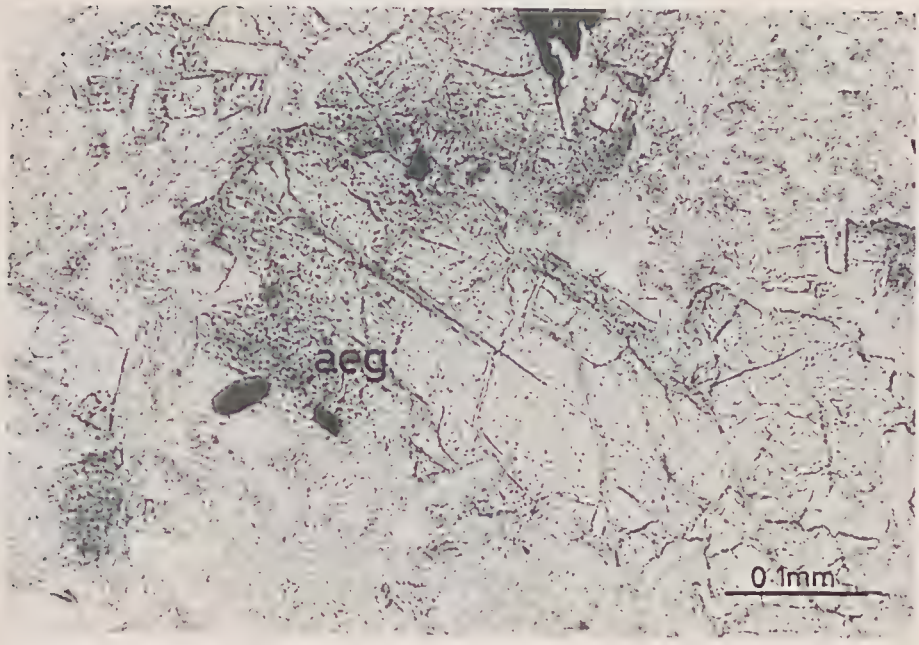
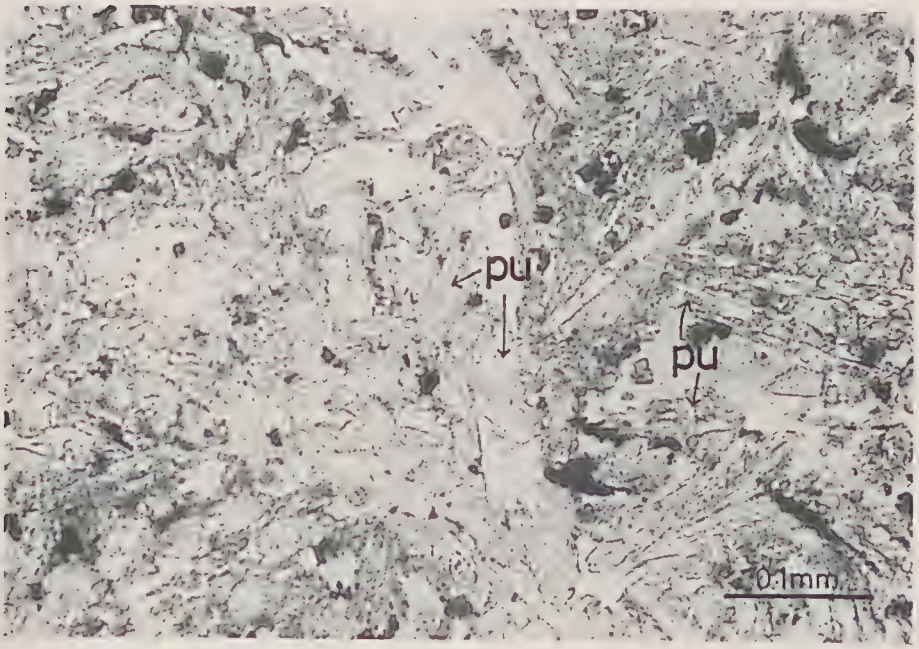


A



B

PLATE 1(a).- Photomicrograph showing aegirine-augitization of relic clinopyroxene. aeg indicates the part of aegirine-augite composition.

PLATE 1(b).- Photomicrograph showing pumpellyite replacing plagioclase in a greenstone of the Motton Spilite.

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A SHORT POLLEN DIAGRAM FROM CROWN LAGOON IN THE MIDLANDS OF TASMANIA

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Reston, Virginia and University of Tasmania.

(with one table and three text-figures)

ABSTRACT

SIGLEO, W.R. and COLHOUN, E.A., 1981 (30 ix): A short pollen diagram from Crown Lagoon in the Midlands of Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 181-188 (with three figures). ISSN 0080-4703. Department of the Interior, Geological Survey, Reston, Virginia, U.S.A. and University of Tasmania, Hobart, Tasmania, Australia.

Pollen analysis of a 2 m core from the floor of Crown Lagoon in the Midlands of Tasmania indicates that the vegetation varied from grassy woodland through grassland to grassy woodland and grassy open-forest during late Pleistocene and Holocene times. It is suggested that these variations represent changes of climate from moister to colder and drier conditions during the later part of the Last Glacial Stage (25 000-10 000 BP) with a return to moister conditions in the Holocene. The core is undated.

INTRODUCTION

During a recent investigation of the stratigraphy of the aeolian sediments that compose a lunette and the clays that floor the adjacent dry lake at Crown Lagoon near Lemont (lat. 42°17'S; long. 147°38'E) in the Midlands of Tasmania (fig. 1) a short core was taken for pollen analysis. The core from the *Upper Unit* of lacustrine clays (Sigleo 1979; Sigleo and Colhoun 1981) was obtained by the Tasmanian Department of Mines whose drilling and seismic work showed that the following stratigraphy occurred beneath the core site located at the obtuse angle on the section line A-B (fig. 2):

0-0.45 m	Very dark grading downwards to dark greyish-brown organic-rich silty clay with a distinct thin horizon of clayey fine quartz sand at 0.45 m.
0.45-2.05 m	Olive-coloured silty clay with 5-10 per cent of very fine quartz sand.
2.05-15 m	Greenish grey to greenish black deeply weathered basalt.
15+ m	Unweathered Tertiary basalt.

This brief paper records the pollen obtained from the core and makes an interpretation of the vegetation and palaeoclimatic history of the area after some general considerations on the present environment and dating of the sediments.

The floor of Crown Lagoon occurs at 375 m on a plateau surface of between 370 and 450 m above sea-level on the eastern boundary of the Midland Graben (350-500 m) with the Eastern Highlands (600-800 m) of Tasmania. The area has cool winters (5°C) and warm summers (15°C), and is sub-humid. Precipitation increases slightly eastwards from 400-500 mm in the rain-shadowed Midlands to 600-700 mm on the Eastern Highlands. West of the Midlands the steep Jurassic dolerite escarpment of the southern part of the Western Tiers rises to 900-1100 m and forms the eastern margin of the Central Plateau which, though cooler, is also a relatively dry region with precipitation values of approximately 700 mm.

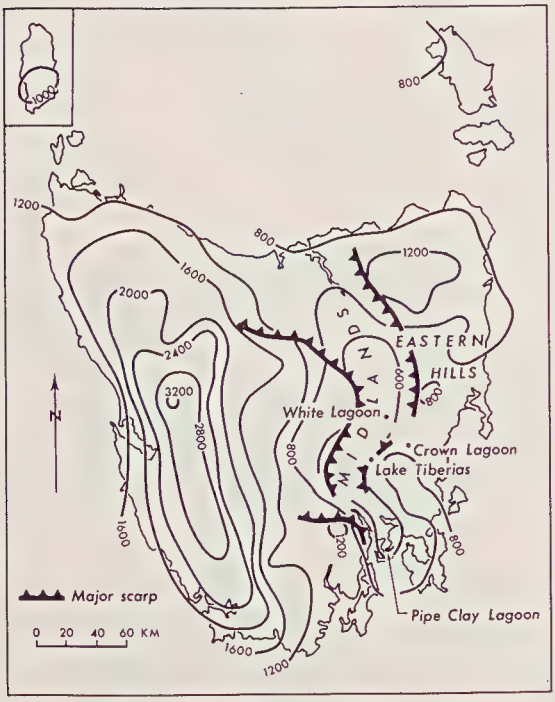

FIG. 1 - Topography and precipitation (mm) in Tasmania.

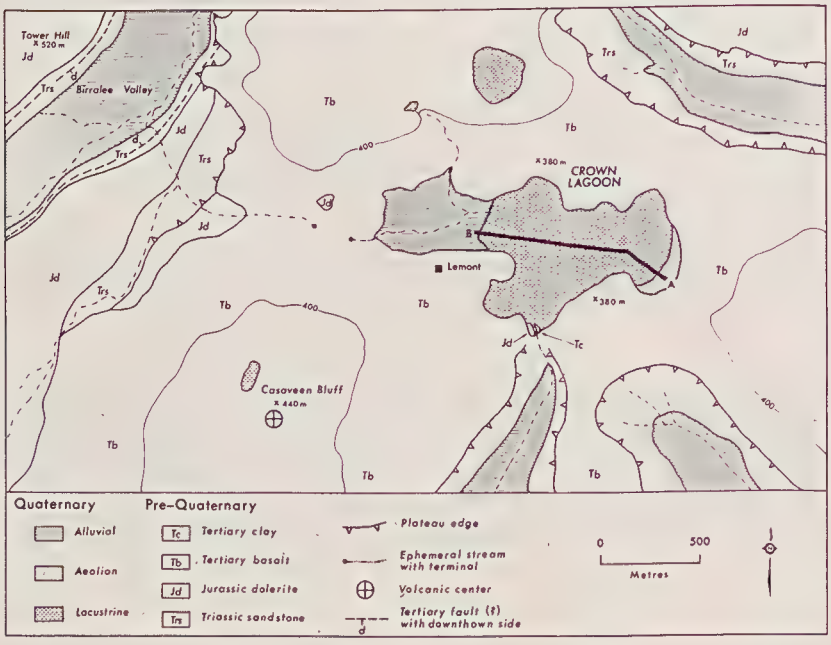

FIG. 2 - Crown Lagoon

There is a broad correlation between the vegetation and climate of these three north-south trending zones which were, prior to the advent of agriculture and lumbering, predominantly occupied by grassy open-forests and woodlands on the Central Plateau, tall open-forests on the scarp of the Western Tiers, grassy woodlands in the Midlands and open-forests with shrub understoreys on adjacent parts of the Eastern Highlands (Specht 1970). On the dolerite escarpment *Eucalyptus delegatensis* is the dominant tree and broadleaf shrubs form an understorey. On the plateau a sequence related to drainage occurs which varies from *E. rodwayi* in poorly-drained depressions through *E. pauciflora* and *E. dalrympleana* with a grass ground layer on gentle slopes to *E. delegatensis* with sclerophyll shrubs on the steepest slopes. The grassy woodlands of the Midlands were dominated by *E. ovata* and *E. pauciflora* with a ground layer of tussock grasses on lower, less well-drained sites, and by *E. viminalis* and *E. amygdalina* on higher, drier ridge sites. *E. delegatensis*, *E. viminalis* and *E. amygdalina* are the most important species of the open-forests on the adjacent part of the Eastern Highlands (Kirkpatrick 1981).

Insufficient organic material was obtained from the core at Crown Lagoon to provide ^{14}C assays to date the lake clays and the vegetation changes as inferred from the pollen content. Although undated it is suggested that the lithological boundary at 0.45 m approximately divides the Pleistocene and Holocene deposits.

POLLEN ANALYSIS

Pollen samples were taken at 0.1 m intervals and were processed using HF digestion and acetolysis (Mehringer 1967) as required for sediments likely to have low pollen concentrations. The pollen taxa were identified and counted at 600x using reference materials supplied by the Botany Department of the University of Tasmania and standard keys. The method of counting employed the double fixed sum procedure (Adam 1967). The first sum of 200 grains included all pollen taxa. To obtain the second sum the values for aquatic taxa were subtracted from the first sum and an additional sum of 200 grains was counted for all non aquatic types. Spores of pteridophytes were excluded. The results are shown separately on the relative pollen diagram of figure 3 as infilled and open curves respectively for individual taxa. The nomenclature follows Curtis and Morris (1975) and Curtis (1963, 1967).

Modern Pollen

For the purposes of interpretation of the relationship between the pollen and vegetation two modern surface samples were taken from within and adjacent to a small undrained marsh 600 m northeast of the lagoon. Each surface sample integrates 36 sub-samples that were collected from a 50 m^2 area at 10 m grid intervals.

Examination of Table 1 suggests that in the grassy woodlands, *Eucalyptus* pollen is overrepresented by a factor of approximately 2 while grass is underrepresented by a factor of 0.6. Pollen of Compositae is grossly overrepresented but the absence of Compositae from the sampled area is not typical for the whole area where both native and introduced Compositae are widespread. Cyperaceae pollen is underrepresented by a factor of 0.5. *Phyllocladus asplenifolius* (1%) is the only long distance indigenous component presently reaching the site and this pollen is windborne a minimum distance of 40 km from the Central Plateau to the west.

In the marsh habitat, which probably most closely resembles the conditions at Crown Lagoon prior to its artificial draining at the end of last century, *Myriophyllum* pollen is underrepresented by a factor of 0.65 while the herbs *Pratia* and *Villarsia* are not represented by pollen. Pollen of Cyperaceae exceeds the presence of *Eleocharis* by a factor of 3.8 and is probably mainly of local habitat origin. In addition, pollen of Myrtaceae, Gramineae and Compositae is recorded in substantial quantities in the marsh assemblage and clearly represents the main components of the local dryland vegetation. As in the grassy woodland, the Myrtaceae pollen (≈ *Eucalyptus*) exceeds the percentage *Eucalyptus* cover by a factor of between 1.3 and 3 to 1, and while the Gramineae pollen overrepresents the local marsh grass it underrepresents the regional grass cover by a factor of 0.25 to 0.35.

TABLE 1

MODERN PLANT SPECIES AND POLLEN ASSEMBLAGES FROM SAMPLE SITES ADJACENT TO CROWN LAGOON

Species	Relative Cover, %		First Sum Pollen, %	Second Sum Pollen, %
	Grassy *Eucalyptus* Woodland			
Eucaluptus ovata	<5		20.0	
Eucalyptus pauciflora	<5			
Banksia marginata	rare		0.5	
Coprosma quadrifida	rare		-	
Poa spp.	45		46.5	
Danthonia spp.	20			
Themeda australis	10			
Convolvulus sp.	5		-	
CYPERACEAE	3		1.5	
Rumex acetosella†	rare		-	
Plantago major†	2		-	
Oxalis corniculata	<1		-	
Acaena echinata	<1		-	
Geranium sp.	rare		-	
Anagallis arvensis†	rare		-	
Pollen taxa only:				
Acacia			0.5	
Bursaria spinosa			0.5	
Casuarina			0.5	
Dodonaea			0.5	
Pinus†			0.5	
Phyllocladus asplenifolius			1.0	
CUPRESSACEAE?†			0.5	
COMPOSITAE			23.0	
Unknowns			4.5	
	Marsh			
Myriophyllum	40		26.0	excl.
Pratia spp.	5		-	-
Villarsia exaltata	30		-	excl.
Eleocharis sp.	5	CYPERACEAE	19.0	excl.
Hydrocotyle sp.	<5		2.0	3.0
GRAMINEAE	<5		18.5	26.0
Triglochin procera	<5		2.0	excl.
Utricularia sp.	<3		-	excl.
Lepidosperma sp.	<1	CYPERACEAE	-	excl.
Juncus sp.	<1		-	excl.
Pollen taxa only:				
Myrtaceae			13.0	30.0
Casuarina			-	1.0
CUPRESSACEAE?†			0.5	1.0
Goodenia			0.5	0.5
COMPOSITAE†(partly)			16.0	34.5
CHENOPODIACEAE/AMARANTHACEAE			-	1.0
Unknowns			2.0	2.5

† introduced species

Compositae pollen again grossly overrepresent their importance in the vegetation of the area. However, the ratios of *Eucalyptus*/Gramineae plus Compositae in the soil surface and in the marsh samples are 0.29 and 0.5 respectively which can be used as guideline values for the modern grassy woodlands even though the Gramineae and Compositae values may be somewhat high as a result of species introduction and agriculture in the area.

Fossil Pollen

Pollen of arboreal taxa rarely exceeds ten per cent in the first sum and twenty per cent in the second sum. The tree pollen consist of a local component of *Eucalyptus* and *Casuarina* and a windborne component of *P. aspleniifolius*, *Phaerosphaera hookeriana*, *Nothofagus cunninghamii* and *Podocarpus lawrencii* most of which has been transported from the western part of the Central Plateau and western Tasmania. Most of the pollen (89-90%) of both sums is derived from local herbs, shrubs and aquatic plants with Gramineae, Compositae, Chenopodiaceae and *Myriophyllum* types being predominant.

Ratios of *Eucalyptus* to Gramineae plus Compositae and of *Eucalyptus* to the wind-pollinated tree taxa have been calculated from the second sum data and graphed as a means of judging the relative importance of trees to herbaceous plants in the local vegetation, and the input of extraneous tree pollen components to the site. Although some of the *Casuarina* may be local its covariance with *P. aspleniifolius* and *P. hookeriana* suggests a more distant source for most of the input.

No pollen was recorded in the sediments below 0.75 m depth. At least the surface 0.1 m (possibly 0.2) of the core have been destroyed either by oxidation of organic matter consequent upon draining and ploughing of the lagoon floor or by mechanical compaction and removal of surface material.

The pollen diagram is divided into three zones on the basis of broad changes in the relative pollen frequencies.

Zone 1 (0.85-1.7+ m) is characterised by relatively high values for *Eucalyptus* (6-16.5%) and windborne pollen of the tree taxa *Casuarina* (3-12%), and *P. aspleniifolius* (3-23%), the shrub *P. hookeriana* (0-6.5%), and by relatively low values of Gramineae (5.5-29%) (second sum). *Myriophyllum* is very abundant (76.5-92.5%).

Zone 2 (0.3-0.8 m) is characterised by low values of *Eucalyptus* (2-6.5%) and wind transported pollen of *Casuarina* (0-2.5%), *P. aspleniifolius* (0-10%) and *P. hookeriana* (0-4%), and by a strong rise in pollen of Granineae (28-52.5%) and Chenopodiaceae (11.5-31%). *Myriophyllum* is greatly reduced (2.5-17.5%).

Zone 3 (0-0.3 m) is characterised by a sharp increase in *Eucalyptus* (16-17%) with some accompanying increase in consistence of presence of *Casuarina* (1-1.5%) and *P. aspleniifolius* (3.5%), and by a marked decrease in pollen of Gramineae 23%. Pollen of *Myriophyllum* (14%) and Cyperaceae (11-18%) increases during this zone.

The high values of *Myriophyllum* in Zone 1 indicate that a shallow lake surrounded at least in part by abundant rooted aquatic plants was present during this period. The relatively high values of wind-pollinated tree taxa suggest that much of the tree pollen was transported into the area which probably had a grassy woodland to open-forest vegetation not markedly dissimilar from the present vegetation, but perhaps with fewer eucalypts as suggested by the ratio to wind-pollinated AP. It is difficult to assess the composition of the herb flora except to indicate that grass was probably more important than the curves of Compositae and Chenopodiaceae would suggest, as the modern samples point to grass being underrepresented and Compositae being grossly overrepresented.

The association of a gross reduction in *Myriophyllum* with very strong increases in Gramineae, Compositae and Chenopodiaceae low in Zone 2, where pollen of distant trees and local *Eucalyptus* was markedly reduced, points strongly to the development of a

Pollen Diagram from Crown Lagoon, Tasmania

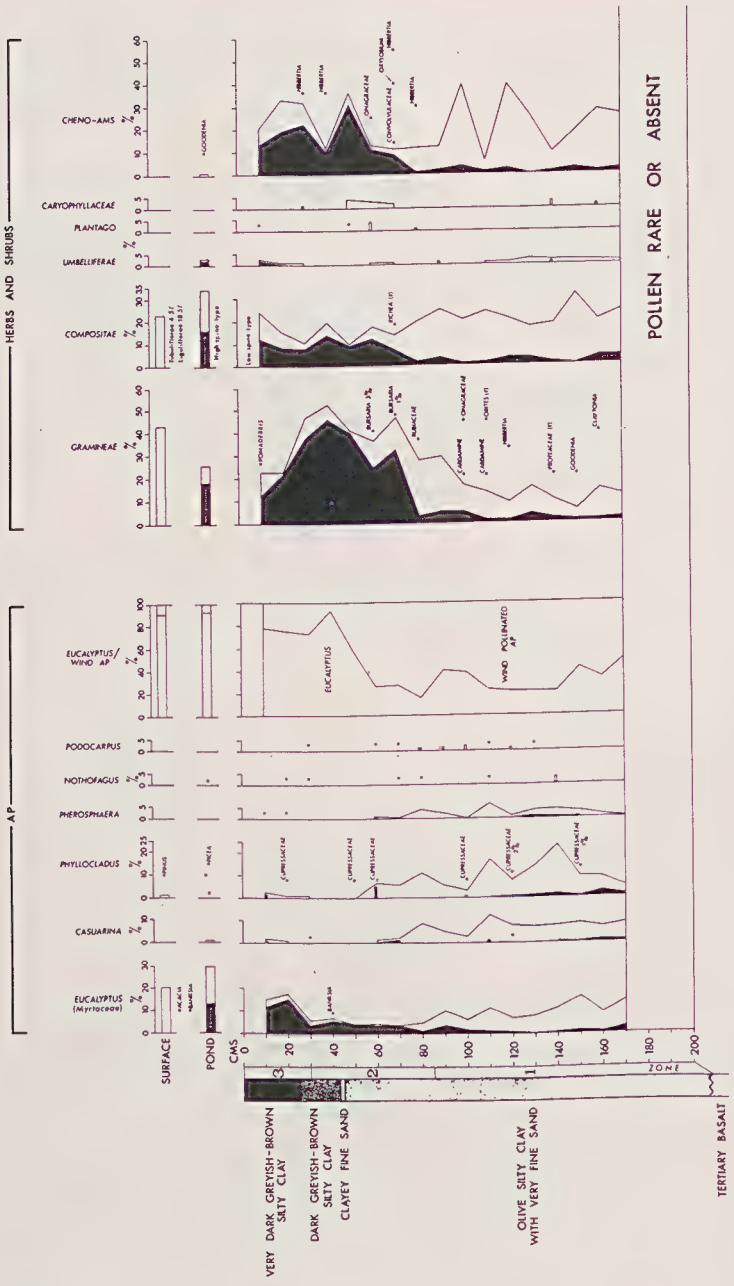

FIG. 3A - Part of pollen diagram.

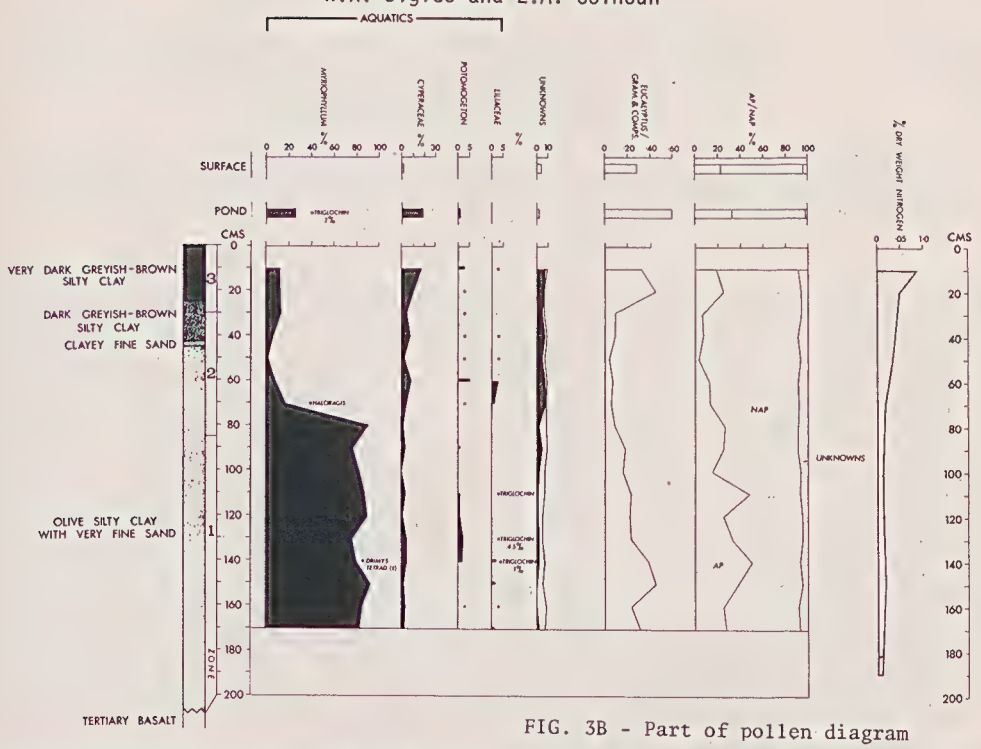

FIG. 3B - Part of pollen diagram

predominantly grassland environment with few trees present. During this period the lagoon probably dried out seasonally sufficiently often not to favour the maintenance of significant quantities of aquatic plants. This suggests that the climate associated with the vegetation of Zone 2 was markedly drier, at least during the summer season than that associated with the vegetation of Zone 1 in which eucalypts and aquatics were more abundant.

During Zone 3 the marked increase in Cyperaceae and nitrogen levels may partly be related to infilling of the lake by organic materials. However, there is both a significant increase in *Eucalyptus* pollen almost to its modern level and a marked decrease of Gramineae also almost to its modern level of deposition in a pond environment. This suggests that Zone 3 represents part of the Holocene vegetation of the area which was grassy woodland and grassy open-forest in a subhumid environment not dissimilar from the present one. It should be noted that the sharp rise in *Eucalyptus* at the base of Zone 3 does not coincide with the main lithological boundary at 0.45 m, taken to be the approximate Pleistocene-Holocene boundary but occurs at the next lithological boundary at 0.25 m. As it has not been possible to obtain ^{14}C assays on either boundary it is difficult to ascertain the time difference that may be involved between the slight increase in organic content of the sediments and the rise in *Eucalyptus*, or its significance. However, a gradual return to more wooded conditions is implied by the steep decrease in the curve for Gramineae between 0.4 and 0.3 m and by the marked increase in *Eucalyptus* above 0.25 m.

From a consideration of the terrestrial and aquatic pollen taxa recorded it may be concluded that during the Late Pleistocene and Holocene at Crown Lagoon the vegetation varied from a grassy woodland through grassland (perhaps steppe) to grassy woodland or grassy open forest with more *Eucalyptus* being present during the Holocene than at any time previously. The vegetation suggests that the climate would have varied from being slightly drier and presumably cooler than at present with permanent water in the lagoon indicating a lack of extreme seasonal differences, through a phase of increased dryness probably

related to reduced temperatures but with marked seasonal differences that caused regular drying out of the lagoon, to approximately the present subhumid climate.

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NEW LOCALITY RECORDS AND PRELIMINARY INFORMATION ON DEMERSAL FAUNAL ASSEMBLAGES IN TASMANIAN WATERS

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(with two tables and three appendices)

ABSTRACT

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A survey of demersal fish resources off the Tasmanian coast in early 1979 provided guideline information on abundance and diversity of resources and the bathymetric distribution of species.

An annotated list of new Australian records includes *Coelorinchus matamua* McCann and McKnight, *Pseudoxenomystax hirsutus* (Castle), *Physiculus marginatus* (Günther), *Pentaceros richardsoni* (Smith) and *Seriolella caerulea* (Guichenot). New Tasmanian records include *Centroscymnus crepidator* (Bocage and Capello), *Centrophorus uyato* (Rafinesque), *Etmopterus lucifer* (Jordan and Snyder), *Dalatias licha* (Bonnaterre), *Raja gudgeri* Whitley, *Harriotta raleighana* Goode and Bean, *Neoscopelus macrolepidotus* Johnson, *Euclichthys polynemus* McCulloch, *Tripterophycis gilchristi* Boulenger, *Neocyttus rhomboidalis* Gilchrist *Cyttosoma boops* Gilchrist, *Lepidotrigla mulhalli* (Macleay), *Platycephalus conatus* Waite and McCulloch, *Neophrynichthys marcidus* McCulloch, *Epigonus denticulatus* Dieuzeide and *Parika scaber* (Forster).

Two skates (*Raja* spp) are new to science, and four other species (*Raja spp.*, *Hydrolagus* sp. and *Pleuroscopus* sp.) have not been positively identified and may be undescribed.

Bathymetric distributions of species sampled and a subjective evaluation of community structures of Tasmanian demersal fishes are provided.

INTRODUCTION

Accurate identification and determination of species compositions are important aspects of both academic and applied studies of animal communities. The population dynamics and natural history of commercial fish species are realised as major considerations in fishery studies but the usefulness of non-commercials in defining faunal assemblages and trophic associations is often undervalued. Such information can often be obtained incidentally from more specific studies at low additional cost. The importance of knowledge relating to interspecific relationships within communities and its application to specific fisheries studies has been discussed by Cushing (1975). The southern extremity of the Australian continental shelf occurs in Tasmanian waters, rendering the area interesting zoogeographically and providing a boundary for many commercial fish species.

Collections of demersal fish from Tasmanian waters date back to voyages of the "Erebus" and "Terror" (1844). The F.I.S. "Endeavour (1909-1914) pioneered trawl fisheries research in southern Australia and while an attempt was made to identify the catch components accurately, most subsequent surveys conducted off Tasmania (Wolfe 1970; Blackburn and Fairbridge 1946; Anon. 1977, 1979a) did not provide detailed compositional data or were basically exploratory surveys of a single species (Grant 1974). On some cruises, "Academic Berg" (Parin and Bekker 1972), "Courageous" (Anon. 1975-78), "Kaiyo Maru" (Anon 1976) "Umitaka Maru" (Scott 1969, 70, 71), more extensive collecting was

undertaken and overall species compositions were provided. Cowper and Downie (1957) provided the only summarised information on depth distribution of species but some species appear to have been confused with closely allied forms.

Prior to 1977 the most comprehensive recent trawling survey off the Tasmanian coast was undertaken by "Zeehaan" (Webb and Wolfe, 1977). In 1977 "Zeehaan" and a Lakes Entrance trawler, "Craigmin", were chartered to undertake exploratory trawling operations around southeastern Australia (Anon. 1977). A further grant allowed for the implementation of phase two of the survey and both vessels were re-chartered for a further exercise in 1978 (Anon. 1979a).

A third phase was completed in 1979. The 23 m stern trawler, "Zeehaan", was chartered for a three month survey off the Tasmanian west coast, and two shots were also completed on the slope off St. Helens. The basic aims were to map and explore uncharted grounds and secondly to obtain detailed information on the composition and bathymetric distribution of species on the continental shelf and slope. The latter objective is discussed in this paper and the former will be covered in detail in a separate report.

METHODS

A total of 57 trawls were made between January 5 and March 23, 1979. Some of the trawls were aborted because of hookups and for a few, incomplete species listings were obtained. Data from 40 complete samples are used in this paper. Stations and their co-ordinates and depth ranges are listed in Appendix 1.

Five trawl nets were used in the survey. These nets and their headline lengths (H.L.) are: Cosalt Three Bridle (36.6 m H.L.), Bridport Gundry 480 (24.4 m H.L.), Cosalt Aquarius (47 m H.L.), Cosalt U.R.I. (36.6 m H.L.) and Cosalt Box Trawl (24.4 m H.L.).

Species compositions for each trawl were obtained and the results plotted in the appropriate subjectively determined depth range; 0-15 (0-27 m), 15-50 (27-91 m), 50-150 (91-274 m), 150-250 (274-457 m), 250-350 (457-640 m) or greater than 350 (640 m) fathoms (Appendix 2). Mean depths were used to categorise trawls where the net operating depths overlapped two depth ranges.

Catch weight estimates for each species were obtained for each trawl and the relative abundances by weight for the ten major species in each depth range given (Appendix 3).

An annotated list of new records and a list of localities is presented. Explanatory notes are given where widely used scientific names for Australian species have been replaced by senior synonyms. Specimens are currently held at the T.F.D.A. Taroona Laboratory but eventually will be distributed between the Australian, Queen Victoria and Tasmanian Museums. New records have been lodged at the Tasmanian Museum; registration numbers (Tas. Mus. No.) are provided.

RESULTS AND DISCUSSION

Taxonomic Notes

SQUALIDAE

Deania calcea (Lowe, 1839)
S22, 24, 28, 33, 35, 37, 38, 39, 40.
This species is listed from Tasmania (Cowper and Downie 1957; Munro 1956) as a junior synonym *D. kaikourae* (Whitley) (Garrick, 1960a)

Centrophorus uyato (Rafinesque, 1810)
S24, 29. (Tas. Mus. No. D 1610).
Superficially resembles the other *Centrophorus* species and was only recently recorded from Australia (Gorman and Graham 1976). The specimens above represent the first record, of the species for Tasmania.

Centroscymnus crepidator (Bocage and Capello, 1864).
S37, 40. (Tas. Mus. No. D 1611)
Recorded from Australia by Gorman and Graham (1978); two specimens above are the first for Tasmania.

Etmopterus lucifer (Jordan and Snyder, 1902).
S25, 27, 29, 32, 36, 39, 40. (Tas. Mus. No. D 1612).
New record for Tasmanian waters.

Squalus blainvillei Risso, 1826).
S17, 23, 25, 27, 29, 30, 31, 32, 36. (Tas. Mus. No. D 1613).
Garrick (1960b), although unable to procure specimens from Australian waters, listed *S. tasmaniensis* Rivero from Tasmania as a junior synonym of this species. Material referred to by Gorman and Graham (1976) and herein confirms the occurrence of this species in Australian waters.

Squalus acanthias (Linnaeus, 1758).
S1.
A cosmopolitan species, commonly found in Tasmanian waters but known by the junior synonym *S. kirki* Phillipps.

DALATIIDAE

Dalatias licha (Bonnaterre, 1788).
S31, 33, 34, 36, 38, 40. (Tas. Mus. No. D 1614).
First record for Tasmania; assumed to be conspecific with *D. phillippsi* (Whitley) which has been recorded from southern Australia (Munro 1956).

RAJIDAE

Raja sp. 1
S7. (Tas. Mus. No. D 1615).
The taxonomy of Australian rajids is confused owing to extreme intraspecific, ontogenetic and sexual variation for fishes that are very similar interspecifically. This species is similar to *R. lemprieri*; although herein discriminated it may eventually be found conspecific with that species.

Raja sp 2
S19, 21, 22, 23, 24, 25, 29, 31, 35, 36, 37, 39. (Tas. Mus. No. D 1616).
Appears to be a valid undescribed species.

Raja sp. 3
S19, 21, 22, 23, 24, 28, 29, 30, 33, 34, 36, 37. (Tas. Mus. No. D 1617).
Appears to be a valid undescribed species.

Raja gudgeri Whitley, 1940.
S29, 36, 37, 39. (Tas. Mus. No. D 1618)
Holotype collected from Great Australian Bight. New Tasmanian record.

Raja sp. 4
S19, 35, 37. (Tas. Mus. No. D 1619)
Similar to and possibly juvenile form of *R. gudgeri*.

CHIMAERIDAE

Hydrolagus sp. 1
S19, 20, 21, 22, 23, 24, 25, 26, 28, 30, 31, 32, 35, 36, 37, 39, 40. (Tas. Mus. No. D 1620).
Allied to *H. lemures* Whitley but differs in some features; may prove to be conspecific with that species.

RHINOCHIMAERIDAE

Harriotta raleighana Goode and Bean, 1894
S33, 34, 37, 39. (Tas. Mus. No. D 1621).
New record for Tasmanian waters.

CONGRIDAE

Pseudoxenomystax hirsutus Castle, 1960
S35, 38. (Tas. Mus. No. D 1622).
Previously known only from New Zealand, the above specimens are the first recorded from Australian waters.

ARGENTINIDAE

Argentina australiae Cohen, 1958
S11, 12.
This species was first described as a subspecies of *A. elongata* Hutton and is now recognised as a valid species (Cohen 1969). Previous Tasmanian records of *A. elongata* are most likely attributable to *A. australiae*.

NEOSCOPELIDAE

Neoscopelus macrolepidotus Johnson, 1863

S38. (Tas. Mus. No. D 1623).
New record for Tasmanian waters.

MORIDAE

Physiculus marginatus (Gunther, 1878)
S23, 24, 32, 36, 37. (Tas. Mus. No. D 1624).
Previously known only from Patagonian waters (Norman 1937); specimens above represent first Australian records for the species.

Euclichthys polynemus McCulloch, 1926
S20, 22, 24, 26, 35. (Tas. Mus. No. D 1625).
A new record for Tasmanian waters. This species is not really a morid, but its true taxonomic position has not been ascertained (Svetovidov 1969).

Tripterophycis gilchristi Boulenger, 1904
S26, 32, 35, 37. (Tas. Mus. No. D 1626).
A new record for Tasmanian waters.

MACROURIDAE

Coelorinchus matamua McCann and McKnight, 1980
S21, 27, 30, 36, 38, 39, 40. (Tas. Mus. No. D 1627).
This species was recently described from New Zealand (McCann and McKnight 1980) and is hereby first recorded for Australia.

Ventrifossa nigromaculatus (McCulloch, 1907)
S22, 26, 28, 35, 37, 40.
Some specimens were collected by "Courageous" (1976) in Storm Bay. This record is now substantiated.

TRACHICHTHYIDAE

Hoplostethus intermedius (Hector, 1875)
S31, 33, 36.
Also collected by "Courageous" (1976) from Tasmanian waters but not recorded as new.

BERYCIDAE

Beryx splendens Lowe, 1833
S21, 23, 30, 32, 33, 34, 35, 36.
Collected in Storm Bay by "Courageous". Appears to be our most common deep water berycid.

ZEIDAE

Cyttus traversi (Hutton, 1872)
S20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 37, 39, 40.
The only Tasmanian record of this common commercial species is in catch data from a previous "Zeehaan" cruise (Anon. 1979a).

OREOSOMATIDAE

Neocyttus rhomboidalis Gilchrist, 1906
S23, 25, 27, 29, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40. (Tas. Mus. No. D 1628).
The species has been recorded from southeastern Australia but not specifically from the Tasmanian shelf where it is extremely abundant.

Cyttosoma boops Gilchrist, 1904
S37, 39, 40. (Tas. Mus. No. D 1629).
New record for Tasmanian waters.

MACRORHAMPHOSIDAE

Centriscops obliquus Waite, 1911
S20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 39.
Recognised by some authors (McCulloch 1929; Munro 1958) as a junior synonym of *C. humerosus* (Richardson). However, the true identity of Richardson's species remains unknown.

Macrorhamphosus scolopax (Linnaeus, 1758)
S11.
The specific status of *M. scolopax* and *M elevatus* Waite is subject to differing schools of thought and requires further taxonomic attention (Scott 1961). The authors are in agreement with Mohr (1937) so only a single cosmopolitan species is listed.

TRIGLIDAE

Lepidotrigla mulhalli (Macleay, 1884)
S2, 3, 5, 6, 7, 8. (Tas. Mus. No. D 1630).
New record for Tasmania. This species and *L. modesta* Waite appear in the past to have been confused with *Paratrigla vanessa* (Richardson).

PLATYCEPHALIDAE

Platycephalus conatus Waite and McCulloch, 1915
S8, 10, 11, 12, 13, 15, 16, 17, 19. (Tas. Mus. No. D 1631).
This species has been previously recorded as *P. speculator* Klunzinger. *P. speculator* most closely resembles *P. richardsoni* Castelnau, but, unlike both other species lacks a swim bladder.

PSYCHROLUTIDAE

Neophrynichthys marcidus McCulloch, 1926
S36, 37, 39. (Tas. Mus. No. D 1632).
Exact locality of the type unknown (Nelson 1977) but samples collected during recent trawling by the "Courageous" have extended its distribution around southern Australia. The above specimens constitute first records for Tasmania.

APOGONIDAE

Epigonus denticulatus Dieuzeide, 1950
S23, 24, 26, 28, 31, 35, 36, 37. (Tas. Mus. No. D 1633).
A cosmopolitan species (Mayer 1974) not previously recorded from Tasmanian waters.

PENTACEROTIDAE

Pentaceros richardsoni (Smith, 1849)
S32. (Tas. Mus. No. D 1634).
A specimen collected from 550 m (300 ftms) represents the first Australian record. The species is apparently rare in New Zealand and South Africa but is caught in commercial quantities in the North Pacific (James 1978) with exceptional catches reported from Hawaiian waters (Anon. 1979b).

Pleuroscopus sp.
S24, 28, 29, 35. (Tas. Mus. No. D 1636).
A South African species *P. pseudodorsalis* Barnard was recently collected (Anon 1979c) in the Western Great Australian Bight. These are the only records of the genus from Australian waters. Tasmanian specimens differ morphometrically and meristically from the holotype but more specimens need to be examined before their relationship can be determined.

CENTROLOPHIDAE

Seriolella Caerulea Guichenot, 1848
S24, 28, 29, 32, 33, 35, 36, 37. (Tas. Mus. No. D 1637).
First Australian record of adults. Juveniles may have been recorded as a separate species. Known from Patagonia (Norman 1937), and New Zealand (Paul 1978).

MONACANTHIDAE

Parika scaber (Forster, 1801)
S2, 5, 6,. (Tas. Mus. No. D 1638).
Originally figured by Scott (1962) incorrectly as *Navodon australis* (Donovan). Although *P. scaber* has been recorded previously as *Navodon setosus* from deep water in Bass Strait (Scott 1960; Waite and McCulloch 1915; Whitley 1931), it was omitted from the Tasmanian records (Hutchins 1977; Last 1975) because of confusion with *Meuschenia australis*.

FAUNAL ASSEMBLAGES

Methods of examining species groupings in some marine studies have been outlined by Sheard (1965). Statistical analyses can only be used with data containing adequate numbers of replicates, hence many (Fish 1925; Sheard 1949; Baker 1954 and Glover 1957) have not attempted to give objective expression to their observations.

Fager and Longhurst (1968) used recurrent group analysis (Fager 1957, 1963) to examine demersal fish assemblages in the tropical eastern Atlantic. They found that where practicable the method can be a useful tool in resource evaluation. However, they highlighted the importance of good subjective techniques when more refined methods cannot be applied to the data. Owing to the low number of sampling replicates, the data obtained in this survey were not analysed statistically.

Subjective analysis indicates the presence of two major distributional zones exhibiting only minor faunal overlap; these are defined by the continental shelf (shallower than 275 m - 150 fathoms) and slope (deeper than 275 m). Interpretation of structuring from a direct comparison of species numbers in the similarity matrix (Table 1) was occluded by the presence of twelve eurybathic species (*Cephaloscyllium laticeps, Galeus boardmani, Galeorhinus australis, Squalus megalops, Squalus blainvillei, Chlorophthalmus nigripinnis, Genypterus blacodes, Macruronus novaezelandiae, Lepidorhynchus denticulatus, Helicolenus papillosus, Rexea solandri,* and *Seriolella punctata*) that occurred both on the shelf and below 460 m (250 ftms). Removal of these species from the matrix (Table 2) provided a better picture of the infra-structure within each zone.

TABLE 1

PERCENTAGE SIMILARITY MATRIX GIVING SPECIES NUMBERS (n) AND OVERLAPPING OCCURRENCE AT EACH DEPTH RANGE

	Depth range (fathoms) [m]	0-15[27]	15-50[91]	50-150[275]	150-250[457]	250-350[640]	>350[640]	n
SHELF	0-15[27]	100	72	33	6	11	0	18
	15-50[91]	20	100	38	9	11	5	65
	50-150[275]	13	53	100	28	28	11	47
SLOPE	150-250[457]	4	24	52	100	84	52	25
	250-350[640]	4	16	29	47	100	69	45
	>350[640]	0	8	14	36	86	100	36

TABLE 2

PERCENTAGE SIMILARITY MATRIX AS IN TABLE 1 BUT WITH THE TWELVE EURYBATHIC SPECIES REMOVED

	Depth range (metres)	0-27	27-91	91-275	275-457	457-640	>690	n
SHELF	0-27	100	69	25	0	0	0	16
	27-91	19	100	31	2	0	0	58
	91-275	11	51	100	11	3	0	35
SLOPE	275-457	0	6	25	100	75	56	16
	457-640	0	0	3	36	100	84	33
	>640	0	0	0	29	84	100	31

Three faunal assemblages appear to be evident on the shelf and upper slope. Although only one sample was taken in less than 27.5 m (15 ftms), elements of a shallow water inshore fauna are apparent. These observations are substantiated by unpublished studies being currently undertaken in the bays and estuaries around Tasmania and in essence are similar to the findings of Walker (1979).

The second, an inner shelf assemblage (27.5 m - 90 m), is well defined, consisting of a fauna which is more diverse than and differs in composition from the outer shelf and slope edge (90-275m). Although these faunas are rather different it is not suggested that the 90 m contour is their "limiting line". Discrete boundaries in faunal distributions are mythical features that are more idealistic than realistic. It is likely that these communities are more complex than indicated in this study and may be further subdivided. Examples of those species most indicative of the inner shelf are *Pristiophorus nudipinnis*, *Lepidotrigla mulhalli* and *Thamnoconus degini* while *Raja nitida*, *Hydrolagus ogilbyi*, *Coelorinchus australis* and *Notopogo lillei* are typical outer shelf species.

The trawled area of slope appears to possess at least two assemblages. An upper slope fauna is well defined with many species occurring down to 730 m (=400 fthms). The best indicators of this community are: *Oxynotus bruniensis*, *Raja* sp. 3, *Euclichthys polynemus*, *Beryx splendens* and *Zenopsis nebulosus*. Suggestions of a fifth assemblage appear with the fringe occurrence, at depths above 550 m, of some species recorded by previous authors (Cowper and Downie 1957; Garrick 1960) as having extended distributions down the slope and probably form part of a mid-slope fauna. Best indicators of this assemblage are: *Mora dannevigi*, *Daenia calcea*, *Scymnodon plunketi*, *Centroscymnus crepidater* and *Dalatias licha* and possibly *Cyttosoma boops*, *Neophrynichthys marcidus* and *Coelorinchus innotabilis*

Problems in viewing all communities as highly stable co-adapted groups in equilibrium have been discussed by Mills (1969). Depth occurrence of some species are further complicated by variations in the physical environment. Work by Fager and Longhurst (1968) support comments by Smith (1950) on the heterogeneity of deep water fish faunas but the importance of temperature in the bathymetric distribution of species is stressed. Newell (1974), in the study of southern Tasmanian water masses, found that waters below the shelf edge were of one type but on the shelf they became complex and exhibited marked seasonal changes. Thermal stratification and shifts in the thermocline in summer may not affect all species, but the distribution of stenothermal species may be slightly deeper at this time of year.

Clearly many questions need answering before community structure in this region is fully understood. Primarily there is a need to establish a better picture of depth distributions of each species and simultaneously examine coexistence patterns to see if the shelf assemblages can be further sub-divided. Bennett and Pope (1953) have shown the presence of distinct faunal provinces on southern Australian shores and there appears to be a similar structuring of reef fish populations (Last 1979). Fager and Longhurst (1968) have shown that inner shelf faunas can sometimes be split into a number of sub-communities. Complex shelf areas such as Bass Strait may possess complex community structures, as indicated by recent Tasmanian studies (unpublished data).

It is well established that the number of fish species is higher in the more ecologically diverse littoral zone than in deeper offshore waters (Smith 1950). This hypothesis is supported by results from this survey. From a total of 129 species, numbers on the shelf and slope totalled 90 and 54 respectively, sample numbers in each zone were almost equal.

Abundance data for each depth range (Appendix 3) suggested a reversal of the above trends. High total catch rates (weight of fish caught/hour) for each of the three slope depth ranges were experienced; similarly, commercial catch rates were higher for the slope samples. However, relative abundance data only provide an approximation to the real situation, as many variables (i.e. tide, net type and time of day) were not constant throughout the sampling. The dangers of using trawl data as an absolute measure of demersal fish abundances are evident from the work of Fenaughty and O'Sullivan (1978).

Faunal lists of littoral fishes from south-eastern Australia (Winstanley 1979) and New Zealand (Webb 1972) are essentially similar in composition to the fauna of Tasmanian waters. Several species appear to be endemic to the southern Australian region (i.e. some rajid, urolophid, platycephalid, pleuronectid, bothid and monacanthid species)

although some are represented by congeners in other seas.

Briggs (1974) regarded the degree of endemism of Tasmanian fishes as lying between 10 and 30 percent, with the Clinidae, Rajidae, Ostraciontidae and Bovichthyidae as major groups. Apart from some rajid species, all members of these families are confined to the shelf, with the possible exception of *Raja* sp. 1, none of the shelf species taken in this survey is endemic to Tasmanian waters. Endemism appears to be greatest in the intertidal and shallow subtidal zones (unpublished data), but the degree is certainly much less than 10 percent.

The slope fauna is widely distributed with several species either antitropically (i.e *Squalus blainvillei*, *Centrophorus uyato* and *Pentaceros richardsoni*) or circumglobally (i.e. *Etmopterus lucifer*, *Coelorinchus fasciatus*) distributed and some may be cosmopolitan. Many species, at this stage, are only "superficial" endemics and increased knowledge of these fishes will result in a reduction in endemism (Smith 1950).

Some features of community compositions require brief discussion. Eight families of elasmobranchs, most of which are commercially important, comprise over 30 percent of the total complement of trawl species compared with about 5 percent in shallow inshore waters. The most diverse of these were the squalids, represented by ten species, which were most numerous on the continental slope. Although most species are widely distributed outside Australian waters, in contrast, all members of two rajiform families, Rajidae (10 species) and Urolophidae (4 species) are endemic to the Australian/New Zealand region. Urolophids, being both viviparous and confined to the shelf, experience only localised dispersal. The more homogeneous physical environment of deep water skates is less restricting, geographically, than for shelf species. However behavioural (in low activity benthics) and reproductive (production of demersal eggs) characteristics are possibly major factors in causing the marked endemism exhibited by the group in different marine provinces throughout the world.

The macrourids are the most diverse family of demersal teleosts in this area. Such findings are in accordance with Pearcy and Ambler (1974), who rank the group as the dominant fishes on the slopes and adjoining abyssal plains of the world. In addition, many species still possibly remain unrecorded in Australian waters (McCann and McKnight 1980). The group is very important commercially (Pechenik and Troyanovskii 1970) and although Tasmanian species are not exploited, a close relative, the merlucciid, *Macruronus novaezelandiae* is potentially Tasmania's most important trawl species. Speciose teleost groups of commercial interest include the morids, triglids, uranoscopids and zeids, while some other less diverse families, such as the ophidiids, platycephalids, cheilodactylids, gempylids, centrolophids and pleuronectids, contain important commercial species.

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APPENDIX 1

TRAWL STATIONS

DEPTH CODE	CRUISE/STATION CODE	START		FINISH		DEPTH RANGE (metres)
		Lat.	Long.	Lat.	Long.	
1	C07 - 10	42°00'S	145°14'E	42°04'S	145°13'E	22
2	C10 - 01	40°20'S	145°25'E	40°23'S	145°20'E	45
3	C12 - 04	39°55'S	144°52'E	39°53'S	145°00'E	46
4	C12 - 03	39°59'S	145°03'E	39°57'S	144°59'E	49
5	C12 - 01	40°04'S	145°07'E	40°06'S	145°09'E	51
6	C12 - 02	39°59'S	145°08'E	39°59'S	145°07'E	51
7	C07 - 01	42°09'S	145°08'E	42°08'S	145°05'E	64
8	C07 - 09	41°56'S	145°00'E	42°00'S	145°02'E	70
9	C11 - 01	40°47'S	144°16'E	40°42'S	144°15'E	90-93
10	C06 - 03	43°18'S	145°33'E	43°15'S	145°31'E	157-159
11	C06 - 01	43°18'S	135°32'E	43°15'S	145°26'E	159
12	C06 - 02	43°15'S	145°26'E	43°20'S	145°31'E	159
13	C06 - 04	43°14'S	145°26'E	43°17'S	145°32'E	159-163
14	C04 - 02	44°03'S	146°55'E	41°01'S	147°07'E	165
15	C09 - 05	40°57'S	143°49'E	40°58'S	143°54'E	183
16	C09 - 06	40°50'S	143°53'E	40°53'S	143°47'E	183
17	C11 - 02	40°46'S	143°42'E	-	-	183-220
18	C04 - 01	44°03'S	146°53'E	-	-	238-265
19	C07 - 03	42°06'S	144°43'E	42°00'S	144°40'E	366-420
20	C07 - 07	42°05'S	144°41'E	42°07'S	144°41'E	455-457
21	C07 - 08	42°07'S	144°41'E	42°08'S	144°43'E	457
22	C09 - 02	41°14'S	144°08'E	41°17'S	144°12'E	457-494
23	C07 - 06	42°08'S	144°41'E	42°03'S	144°39'E	485-547
24	C09 - 04	41°01'S	143°51'E	40°54'S	143°44'E	494
25	C07 - 05	42°12'S	144°43'E	42°08'S	144°40'E	530-567
26	C02 - 01	40°48'S	143°36'E	40°41'S	143°31'E	550
27	C03 - 01	42°20'S	144°47'E	-	-	550
28	C09 - 01	41°19'S	144°11'E	41°14'S	144°05'E	550
29	C11 - 04	40°43'S	143°33'E	40°47'S	143°36'E	550
30	C15 - 01	40°32'S	143°27'E	40°39'S	143°30'E	550
31	C15 - 02	40°55'S	143°55'E	-	-	550
32	C15 - 03	41°05'S	143°54'E	-	-	550
33	C17 - 01	41°33'S	148°38'E	41°36'S	148°38'E	550
34	C17 - 02	42°23'S	148°33'E	42°17'S	148°39'E	550
35	C09 - 03	41°10'S	144°01'E	41°02'S	143°52'E	530-640
36	C06 - 05	42°14'S	144°43'E	42°21'S	144°47'E	622-658
37	C08 - 03	41°20'S	144°12'E	41°15'S	144°03'E	622-722
38	C08 - 02	42°15'S	144°43'E	42°19'S	144°46'E	680-710
39	C11 - 03	40°40'S	143°29'E	-	-	677-750
40	C08 - 01	42°21'S	144°45'E	42°15'S	144°43'E	732

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

Depth (m)	< 27	27 - 91								91 - 275									275 - 457												457 - 640												> 640			
SPECIES Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
HETERODONTIDAE																																														
Port Jackson shark																																														
Heterodontus portusjacksoni			x	x	x																																								
HEXANCHIDAE																																														
seven-gilled shark																																														
Notorhynchus cepedianus	x																																												
ORECTOLOBIDAE																																														
rusty catshark																																														
Parascyllium ferrugineum	x	x	x			x	x																																						
SCYLIORHINIDAE																																														
draughtboard shark																																														
Cephaloscyllium laticeps		x	x	x		x		x			x	x	x	x	x			x	x	x	x	x	x					x			x	x	x	x		x							
spotted catshark																																														
Asymbolis analis		x			x			x		x	x	x	x	x																														
sawtail shark																																														
Galeus boardmani												x			x		x	x		x	x	x	x	x	x			x				x	x		x									
CARCHARHINIDAE																																														
gummy shark																																														
Mustelus antarcticus	x	x	x	x		x	x		x		x	x																																		
school shark																																														
Galeorhinus australis		x				x		x		x	x	x		x	x	x		x	x					x																					
SQUALIDAE																																														
prickly dogfish																																														
Oxynotus bruniensis																			x			x		x	x			x		x		x		x	x						x		
long snouted dogfish																																														
Deania quadrispinosa																																												x		
brier shark																																														
Deania calcea																						x		x				x					x		x			x	x		x	x	
southern dogfish																																														
Centrophorus uyato																								x					x															
Lord Plunket's shark																																														
Scymnodon plunketi																																					x									
Mollers deepsea shark																																														
Etmopterus lucifer																									x		x		x				x			x						x	x	
spiked dogfish																																														
Squalus megalops	x				x	x	x	x		x	x	x	x		x	x	x	x											x																
green-eyed dogfish																																														
Squalus blainvillei																	x						x		x		x		x	x	x	x			x									
white-spotted dogfish																																														
Squalus acanthias	x																																													
golden dogfish																																														
Centroscymnus crepidator																																					x									

APPENDIX 2

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

Depth (m)	< 27	27 - 91							91 - 275								275 - 457										457 - 640										> 640			
SPECIES Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
DALATIIDAE																																								
black shark																																								
Dalatias licha																															x		x	x		x		x		x
PRISTIOPHORIDAE																																								
southern saw shark																																								
Pristiophorus nudipinnis	x	x	x	x	x	x		x																																
common saw shark																																								
P. cirratus			x	x		x	x		x		x	x	x	x																										
SQUATINIDAE																																								
angel shark																																								
Squatina australis	x		x		x	x							x																											
RAJIDAE																																								
thornback skate																																								
Raja lemprieri				x			x	x		x	x	x	x	x																										
brown blotched skate																																								
Raja sp. 1							x																																	
white spotted skate																																								
Raja cerva		x		x		x					x	x	x			x	x	x	x																					
long-nosed skate																																								
Raja nasuta					x	x							x																											
grey skate																																								
Raja sp. 2																			x		x	x	x	x	x				x		x				x	x	x		x	
Melbourne skate																																								
Raja whitleyi				x				x					x																											
green bight skate																																								
Raja sp.3																			x		x	x	x	x				x	x	x			x	x		x	x			
brown bight skate																																								
Raja gudgeri																													x							x	x		x	
blotched bight skate																																								
Raja sp. 4																			x																x					
peacock skate																																								
Raja nitida												x	x	x	x																										
UROLOPHIDAE																																								
banded stingaree																																								
Urolophus cruciatus	x	x		x	x		x	x	x				x		x																									
stingaree																																								
Urolophus paucimaculatus	x																																							
sandy-backed stingaree																																								
Urolophus bucculentus							x	x	x	x																														
green back stingaree																																								
Urolophus viridis			x	x	x	x	x	x	x	x																														
MYLIOBATIDAE																																								
eagle ray																																								
Myliobatis australis				x																																			

APPENDIX 2

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

SPECIES	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	Depth (m)	< 27			27 - 91								91 - 275							275 - 457									457 - 640									> 640			
TORPEDINIDAE																																									
torpedo ray																																									
Narcine tasmaniensis					x	x	x	x	x	x		x	x		x																											
electric ray																																									
Torpedo macneilli					x																																				
RHINOBATIDAE																																									
fiddler ray																																									
Trygonorhina fasciata				x																																				
CALLORHYNCHIDAE																																									
elephant fish																																									
Callorhynchus milii		x						x	x	x																															
CHIMAERIDAE																																									
Ogilby's ghost shark																																									
Hydrolagus ogilbyi														x		x	x		x																						
ghost shark																																									
Hydrolagus sp. 1																				x	x	x	x	x	x	x	x		x		x	x	x			x	x	x		x	x
RHINOCHIMAERIDAE																																									
spookfish																																									
Harriotta raleighana																																		x	x		x		x		
CONGRIDAE																																									
little conger eel																																									
Gnathophis habenata								x																																	
deepsea conger eel																																				x			x		
Pseudoxenomystax hirsutus																																									
ARGENTINIDAE																																									
silverside																																									
Argentina australiae												x	x																												
CHLOROPTHALMIDAE																																									
cucumber fish																																									
Chloropthalmus nigripinnis											x	x	x	x	x	x	x		x	x	x	x	x	x	x			x	x	x	x	x			x						
NEOSCOPELIDAE																																									
large-scaled lantern fish																																							x		
Neoscopelus macrolepidotus																																									
MORIDAE																																									
red cod																																									
Pseudophycis bachus		x	x					x	x	x	x	x		x																											
deep sea cod																																									
Mora dannevigi																							x	x		x		x		x	x	x	x	x	x		x	x	x		x

APPENDIX 2 DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

Depth (m)	<27	27 - 91								91 - 275									275 - 457										457 - 640																>640			
SPECIES Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Tasmanian cod																																																
Physiculus marginatus																							x	x								x				x	x										
Eucla cod																																																
Euclichthys polynemus																				x		x		x		x									x											
grenadier cod																																																
Tripterophycis gilchristii																										x						x			x		x									
OPHIDIIDAE																																																
rock ling																																																
Genypterus blacodes		x				x			x	x	x	x				x	x						x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MACROURIDAE																																																
southern whiptail																																																
Coelorinchus australis										x	x	x	x		x	x	x	x	x																													
banded whiptail																																																
Coelorinchus fasciatus																			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x						
large headed whiptail																																																
Coelorinchus matamua																					x						x			x						x			x	x	x					
innotable whiptail																																																
Coelorinchus innotabilis																																				x	x	x	x									
toothed whiptail																																																
Lepidorhynchus denticulatus																x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x						
blackspot whiptail																																																
Ventrifossa nigromaculata																						x				x		x								x			x							
MERLUCCIIDAE																																																
blue grenadier																																																
Macruronus novaezelandiae																	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x						
TRACHICHTHYIDAE																																																
New Zealand sawbelly																																																
Hoplostethus intermedius																															x		x			x									
sandpaper fish																																																
Paratrachichthys trailli							x																																									
BERYCIDAE																																																
alfonsin																																																
Beryx splendens																					x		x							x		x	x	x	x	x									
ZEIDAE																																																
king dory																																																
Cyttus traversi																				x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x							
silver dory																																																
Cyttus australis		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																													
mirror dory																																																
Zenopsis nebulosus																		x	x	x	x	x																									
John dory																																																
Zeus faber			x		x	x																																										

APPENDIX 2

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

Depth (m)	< 27	27 - 91								91 - 275									275 - 457																457 - 640																> 640			
SPECIES Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
New Zealand dory																																								
Cyttus novaezelandiae										x	x	x		x			x	x																						
OREOSOMATIDAE																																								
spiky dory																																								
Neocyttus rhomboidalis																							x		x		x		x		x	x	x	x	x	x	x	x	x	x
ox-eyed dory																																								
Cyttosoma boops																																					x		x	x
MACRORHAMPHOSIDAE																																								
banded bellows fish																																								
Centriscops obliquus																				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	
common bellows fish																																								
Macrorhamphosus scolopax											x																													
crested bellows fish																																								
Notopogon lillei											x	x			x	x		x																						
SCORPAENIDAE																																								
red gurnard perch																																								
Helicolenus papillosus									x	x	x	x	x		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
thetis fish																																								
Neosebastes thetidis		x	x	x		x			x	x	x	x	x		x	x	x																						
common gurnard perch																																								
Neosebastes scorpaenoides					x																																		
goblin fish																																								
Glyptauchen panduratus		x				x																																		
TRIGLIDAE																																								
red gurnard																																								
Chelidonichthys kumu							x		x																															
latchet																																								
Pterygotrigla polyommata	x					x	x	x	x	x	x	x	x	x	x	x	x	x																						
butterfly gurnard																																								
Paratrigla vanessa	x		x	x	x	x	x																																	
round snouted gurnard																																								
Lepidotrigla mulhalli		x	x		x	x	x	x																																
grooved gurnard																																								
Lepidotrigla modesta				x	x	x	x	x	x	x	x	x	x	x																										
PLATYCEPHALIDAE																																								
tiger flathead																																								
Platycephalus richardsoni			x	x	x	x	x	x	x			x	x																											
deep-water flathead																																								
Platycephalus conatus								x		x	x	x	x		x	x	x		x																					

APPENDIX 2

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

SPECIES	Depth (m)	< 27	27 - 91								91 - 275									275 - 457													457 - 640													> 640			
	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
toothed whiptail																		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Lepidorhynchus denticulatus																																															
blackspot whiptail																							x				x		x							x		x								
Ventrifossa nigromaculata																																															
sand flathead		x		x	x	x	x			x																																					
Platycephalus bassensis		x		x	x	x	x			x																																					
HOPLICHTHYIDAE																																															
deep sea flathead																				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Hoplichthys haswelli																																														
PSYCHROLUTIDAE																																															
blobfish																																					x	x		x							
Neophrynichthys marcidus																																															
CALLIONYMIDAE																																															
common stinkfish				x																																											
Callionymus calauropomus																																															
long spined stinkfish												x																																			
Callionymus phasis																																															
SERRANIDAE																																															
rosy perch																		x																													
Callanthias allporti																																															
orange perch																		x	x																												
Anthias pulchellus																																															
hapuku																x																														
Polyprion oxygeneios																																															
CARANGIDAE																																															
jack mackerel				x																																											
Trachurus declivis																																															
EMMELICHTHYIDAE																																															
redbait					x																																										
Emmelichthys nitidus																																															
APOGONIDAE																																															
big-eye cardinal fish																								x		x						x				x		x	x	x	x	x	
Epigonus lenimen																																															
white cardinal fish																								x	x	x	x		x			x					x	x	x					
Epigonus denticulatus																																															
GERREIDAE																																															
silverbelly				x	x																																										
Parequula melbournensis																																															

APPENDIX 2 DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

SPECIES	Depth (m)	< 27	27 - 91							91 - 275									275 - 457			457 - 640												> 640			
	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
gemfish																																									
Rexea solandri								x			x	x	x	x		x	x	x	x	x				x	x	x	x		x	x	x	x	x	x	x		x			x	x
CENTROLOPHIDAE																																									
deep sea trevalla																																									
Hyperoglyphe antarctica																				x																					
spotted trevalla																																									
Seriolella punctata		x	x		x			x		x														x	x	x					x	x	x				x				
white trevalla																																									
Seriolella caerulea																									x				x	x			x	x			x	x			
PLEURONECTIDAE																																									
long-snouted flounder																																									
Ammotretis rostratus		x																																						
spotted flounded																																									
Ammotretis liturata				x																																				
greenback flounder																																									
Rhombosolea tapirina		x																																						
BOTHIDAE																																									
Andrew's flounder																																									
Arnoglossus andrewsi				x																																				
TETRAODONTIDAE																																									
ringed toadfish																																									
Arothron armilla			x	x																																				
OSTRACIONTIDAE																																									
Shaws cowfish																																									
Aracana aurita			x	x	x	x	x																																		
MONACANTHIDAE																																									
cosmopolitan leatherjacket																																									
Parika scaber			x			x	x																																		
Degen's leatherjacket																																									
Thamnaconus degeni			x		x	x	x			x																															
mosaic leatherjacket																																									
Eubalichthys mosaicus			x	x			x																																		
DIODONTIDAE																																									
porcupine fish																																									
Allomycterus pilatus									x	x	x	x	x			x																									
globe fish																																									
Diodon nichthemerus		x	x	x																																					

APPENDIX 2

DEPTH DISTRIBUTIONS OF FISH SPECIES COLLECTED BY 'ZEEHAAN', JANUARY TO MARCH 1979

Depth (m)	< 27	27 - 91								91 - 275									275 - 457											457 - 640											> 640			
SPECIES Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
SPARIDAE																																											
snapper																																											
Chrysophrys auratus				x																																						
MULLIDAE																																											
red mullet																																											
Upeneichthys lineatus		x																																								
PENTACEROTIDAE																																											
giant boarfish																																											
Paristiopterus labiosus								x																																			
black-spotted boarfish																																											
Zanclistius elevatus											x				x	x	x																										
pelagic armourhead																																											
Pentaceros richardsoni																																x											
long-snouted boarfish																																											
Pentaceropsis recurvirostris		x	x		x	x			x																																	
OPLEGNATHIDAE																																											
knife jaw																																											
Oplegnathus woodwardi															x	x																										
CHEILODACTYLIDAE																																											
morwong																																											
Nemadactylus macropterus							x		x	x	x	x	x				x																										
PARAPERCIDAE																																											
barred grubfish																																											
Parapercis allporti											x	x																															
CREEDIDAE																																											
Haswells sandfish																																											
Creedia haswelli			x																																							
URANASCOPIDAE																																											
bulldog stargazer																																											
Gnathagnus innotablis										x																																	
barred stargazer																																											
Kathetostoma laeve		x	x	x	x	x		x																																			
speckled stargazer																																											
Kathetostoma giganteum								x		x	x	x	x	x	x			x	x																								
scaled stargazer																																											
Pleuroscopus sp.																								x				x	x							x						
GEMPYLIDAE																																												
snoek																																											
Thyrsites atun			x																																								

APPENDIX 3

RELATIVE ABUNDANCE BY WEIGHT FOR EACH DEPTH RANGE (METRES) OF THE TEM MAJOR SPECIES GIVING THEIR PERCENTAGE CONTRIBUTION (p) TO THE TOTAL CATCH WEIGHT (w) AT THAT DEPTH FROM n SAMPLES. TOTAL (C_T) AND COMMERCIAL (C_c) CATCH RATES ARE ALSO GIVEN.

1. 0-29 metres

	% weights
Elephant fish	33.5
Sand Flathead	12.9
Banded Stingaree	8.4
Bearded Rock Cod	8.4
Butterfly Gurnard	8.4
Latchet	8.4
Spiked Dogfish	4.5
Southern Sawshark	4.5
Rusty Catshark	2.2
Gummy Shark	2.2

p = 93.4%
w = 179 kg C_T = 119.4 kg/hr
n = 1 C_c = 67.9 kg/hr

2. 27-91 metres

	% weights
Green Back Stingaree	32.1
Bearded Rock Cod	24.5
Rounded Snouted Gurnard	8.3
Latchet	3.6
Banded Stingaree	3.4
Thetis Fish	3.2
Gummy Shark	1.9
Angel Shark	1.8
Arrow Squid	1.6
Elephant Fish	1.6

p = 82.0
w = 3359 C_T = 207.6 kg/hr
n = 8 C_c = 84.45 kg/hr

3. 91-275 metres

	% weights
Jackass Fish	22.1
Latchet	12.5
Porcupine Fish	7.7
Cucumber Fish	6.7
School Shark	6.3
Speckled Stargazer	5.1
Ogilby's Ghost Shark	5.0
Spiked Dogfish	4.5
Denticulated Skate	3.8
Southern Calamary	2.9

p = 76.6%
w = 4826 kg C_T = 181.9 kg/hr
n = 9 C_c = 104.19 kg/hr

4. 275-457 metres

	% weights
Toothed Whiptail	65.8
Blue Grenadier	14.2
Mirror Dory	7.5
Green Bight Skate	2.5
Banded Whiptail	2.1
Deepwater Ghost Shark	1.3
School Shark	1.3
Draughtboard Shark	1.1
Red Gurnard Perch	1.1
Spiny Flathead	1.1

p = 98.0%
w = 1800 kg C_T = 502.3 kg/hr
n = 3 C_c = 129.2 kg/hr

5. 457-640 metres

	% weights
King Dory	35.4
Toothed Whiptail	18.2
Blue Grenadier	16.6
Red Gurnard Perch	9.7
Banded Bellows Fish	4.5
Spiky Dory	2.8
Deepwater Ghost Shark	1.8
Gemfish	1.7
Deep Sea Cod	1.5
Rockling	1.4

p = 92.6%
w = 24760 kg C_T = 342.32 kg/hr
n = 15 C_c = 243.6 kg/hr

6. Greater than 640 metres

	% weights
Spiky Dory	58.3
Toothed Whiptail	11.3
Deep Sea Cod	3.6
King Dory	3.3
Red Gurnard Perch	2.9
Banded Bellows Fish	2.7
Southern Whiptail	2.7
Brier Shark	2.5
Rockling	2.4
Deepwater Ghost Shark	1.9

p = 91.6%
w = 5646 kg C_T = 442.8 kg/hr
n = 4 C_c = 333.7 kg/hr

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CONSERVATION OF THE MOUNT CAMERON WEST ENGRAVING SITE, NORTHWESTERN TASMANIA

by P.J. Hughes, A.L. Watchman and M.E. Sullivan
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(with two tables, one text-figure and two plates)

ABSTRACT

HUGHES, P.J., WATCHMAN, A.L. and SULLIVAN, M.E., 1981 (30 ix): Conservation of the Mount Cameron West engraving site, northwestern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 115, 211-222 (with one figure and two plates). ISSN 0080-4703. Department of Prehistory, Australian National University, Canberra, A.C.T., Australia.

A study of the site and its surroundings indicates that the geochemical environment is such that although the aeolian calcarenite on which the engravings are executed is soft and friable, it is not undergoing appreciable chemical or physical weathering, at least in the short-term. In contrast the site is under considerable threat from coastal erosion. This threat could be reduced, if not eliminated, through the implementation of coastal erosion control measures.

INTRODUCTION

The Mount Cameron West Aboriginal Site in northwestern Tasmania contains a set of engravings widely regarded as being of international cultural significance. The land on which the site occurs was acquired by the National Parks and Wildlife Service of Tasmania in February 1977 and was proclaimed a State Reserve in June 1978. Ultimately the Service will prepare a long-term programme for the conservation, presentation and interpretation of the site. As a step towards this goal we have undertaken, on a consultancy basis, a preliminary geological and geomorphological investigation in relation to the deterioration, conservation and management of the site (Hughes, Watchman and Sullivan 1979), the results of which are reported in this paper.

The fieldwork for this project was carried out with the assistance of G. Melville, Ranger, North-West Region, in July 1979. Field observations were made of the engraving site and its surroundings, and samples of rock and sand were collected for mineralogical, physical and chemical analyses at the Australian National University.

The findings of this study are based not only on the results of this fieldwork and the subsequent analyses, but also on a review of published and unpublished documents relating to the site and extensive discussions with Dr Rhys Jones, Department of Prehistory, Research School of Pacific Studies, ANU, and with Professor Bruce Thom, Department of Geography, Royal Military College, Duntroon.

PHYSICAL SETTING

The rock engravings are on two outcrops of aeolian calcarenite at the northern end of a 3 km long sandy beach (fig. 1). The southern outcrop is separated from that to the north by a gully about 200 m wide which is partly filled with sand. This outcrop lies immediately behind the foredune and within an active blowout and is now almost completely buried in mobile sand. Because of this we are unable to comment on conservation problems specific to this outcrop.

The northern outcrop forms a prominent bluff about 6 m high (plate 1) and the engravings have been executed both on the cliff face and on slabs fallen from the face now forming a talus deposit between the foot of the cliff and the present high tide limit. Most of the block talus deposit with its engravings is now buried in sand, presumably that used to cover the site in 1971 (McCarthy n.d., p.17). At present only panel 24, the top

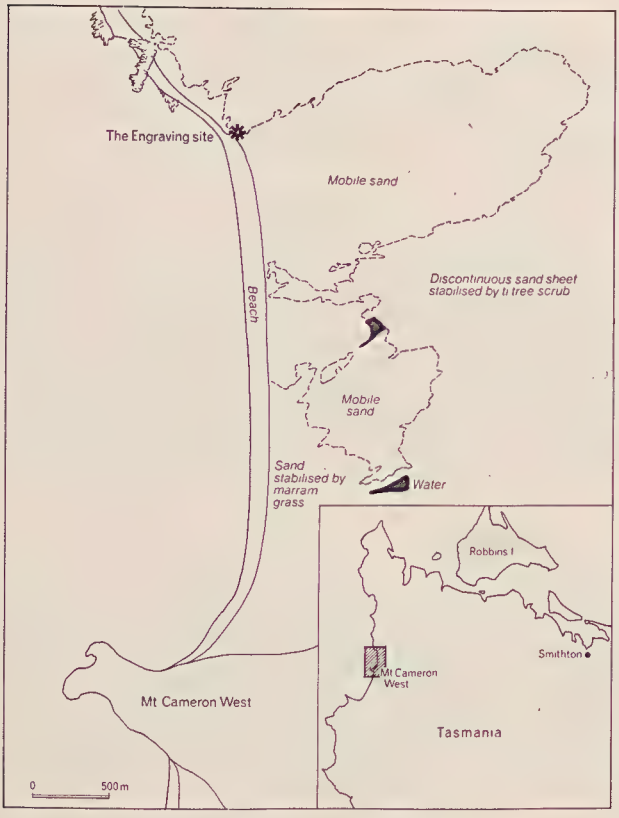

FIG. 1.- Location and setting of the Mount Cameron West engraving site. Map drawn from an aerial photograph taken in February 1979.

of panel 13, and part of panel 1 are still exposed (the numbering system used to identify the engraved panels is that of Luckman (1951a and b) as modified by McCarthy (n.d., p.20). A wire fence has been constructed around the site to exclude stock, and marram grass has been extensively planted to stabilise the sand cover and to encourage further sand trapping.

Behind and to the south of the site is an active eastnortheast trending blowout 1 km across and 2 km long, the northern limit of which extends inland from behind the main (north) engraving site.

The climate of the region is temperate marine, and the average annual rainfall is about 1150 mm (Richley 1978). Although rainfall is greatest in winter, there is no dry period. January has the lowest average monthly rainfall (with about 45 mm at Marrawah) and as it is at this time that potential evaporation is highest, evaporation may then exceed rainfall. Hence during the height of summer the calcarenite and its loose sand cover may dry out. Onshore winds predominate, and are commonly strong.

PREVIOUS INVESTIGATIONS

It is generally agreed that the site was covered by sand with a thick tea-tree and other scrub cover in the early 1830s when George Augustus Robinson passed close by several times (Jones in press, McCarthy n.d., p.3). It is likely that this sand cover remained until shortly before the site was reported to Meston in the early 1930s (Meston 1933, 1934). Since that time several people have commented on the state of preservation, and problems of conservation of the site.

Meston commented that the 'friable calcareous sandstone is soft and easily worked, but hardens on contact with the air. In consequence of its friable nature many of the carvings are badly weathered, and all show marks of erosion' (Meston 1933, p.2). Elsewhere (1934, p.182) he noted that 'one mass...(is)...entirely covered with motifs, some badly weathered, others in a good state of preservation'. Although in his study Meston examined both outcrops, these comments refer mainly to the southern outcrop, which at that time was almost totally stripped of sand.

Luckman first visited the area in 1949 and noted that one of the panels in the southern outcrop, described by Meston, was 'in an advanced state of erosion' (1951a, p.2). One year later, when he returned to the site, he found that same panel had broken into three pieces, and that the whole engraved surface had flaked away from the main block (1951a, p.2).

Luckman then undertook a further study of the northern outcrop which involved

PLATE 1.- The northern outcrop of the Mount Cameron West Aboriginal site showing the partial sand cover and the close proximity of the high tide limit. The blowout is in the right background.

extensive removal of the sand covering the engraved blocks forming the talus deposit at the foot of the cliff. He noted that 'where the covering sand was damp, particularly on horizontal surfaces, erosion was so advanced that the carved rock had literally merged into the sand itself, while those carvings which had become covered with vegetation flaked off through the penetration into the sandstone layers of countless fine rootlets' (1951a, p.6).

In 1969 Jones and Lourandos undertook a major archaeological study of the site and McCarthy recorded the engravings in detail. The results of the archaeological study indicate that the engravings were completed before 1350BP, that from that time until about 850BP the site was used as a campsite, and that after 850BP the site was abandoned and became covered with sand and scrub (Jones in press). At that time Jones observed that when initially excavated the aeolian calcarenite was extremely soft, but hardened when exposed to the air such that after five days it was able to withstand the pressure of casting.

In his report on the rock engravings recorded in this study, McCarthy (n.d., p.10-20) has compiled a list of opinions on, and suggestions for the conservation of the engravings expressed since 1931 (including those of Meston and Luckman), none of which, he notes, has been heeded or acted upon by the relevant authorities. The solutions proposed for conserving the engravings depend upon what is perceived to be the major threat to their survival; generally either physical or chemical disintegration of the rock, or destruction by storm wave erosion, or occasionally both. In all instances the only

permanent solution offered is that the engraved panels be sawn off and removed for safe-keeping to museums. Other solutions proposed to protect the engravings *in situ* include the stabilisation of the rock surfaces with surface consolidants and the construction of a sea-wall or a protective foredune.

RESULTS OF THIS INVESTIGATION

The geology of the site

Methods -

Field descriptions were made of the site, particularly its geology and geomorphology, and the nature and condition of the rock surface and its engravings. In order to observe the condition of the rock and the engravings below the surface of the protective cover of loose sand, a small pit, about 0.5 m deep was dug adjacent to panel 13. Samples of the rock, of a gelatinous precipitate exuding from a number of pits and fissures in the rock, and of unconsolidated sand from on and around the site were collected and subsequently analysed.

The field pH of each sample of unconsolidated sand was measured to the nearest 0.5 of a pH unit using a CSIRO Soil pH Test Kit. The calcium carbonate contents of both the rock samples and samples of unconsolidated sand were determined in the laboratory using the rapid gravimetric method of Bauer, Beckett and Bie (1972). The air-dry colour of each sample was determined in the laboratory using a Munsell colour chart.

The grain size of the unconsolidated sands was determined by dry sieving (Folk 1974) and their mineralogy and grain morphology by examination under a binocular microscope. X-ray diffraction (XRD), infrared spectroscopy (IRS) and X-ray fluorescence (XRF) analyses were also carried out on the sands, to determine their chemical compositions and constituent minerals.

Four samples of the rock were analysed. Two were collected during this study from exposed surfaces; one from the cliff face and the other from the boulder on which the engraved panel 1 is executed. The other two were originally collected by Jones during the 1969 excavations, and came from beneath the sand mantle. All rock samples were thin-sectioned and petrographic descriptions were made. The mineralogy and grain morphology of the acid insoluble residues of these samples were also described, XRD and IRS were carried out on the rock samples to determine the precise compositions of their constituent carbonates and associated salts. Detailed scanning electron microscope studies of the surface layers of the samples collected from the exposed cliff face and boulder were carried out to determine the nature of the weathering crust. The two samples collected by Jones were also analysed by XRF for major elements. The composition of the gelatinous exudation from the rock was determined by XRD and IRS.

The major element contents of the samples of sand and of buried rock collected by Jones were analysed by XRF according to the method of Norrish and Hutton (1969). The volatile components (water and carbon dioxide) and sodium cannot be measured by this method and the results were therefore calculated on a volatile and sodium-free basis (table 2b). When these analyses are recalculated on a quartz-free basis with all totals to 100% (table 2b) they give a good indication of the relative geochemical environments of the sand and the buried calcarenite.

Composition of the rock and the unconsolidated sand -

The rock on which the engravings are executed is aeolian calcarenite. This calcarenite consists of well-rounded shell fragments up to 1 mm in length, and occasional quartz grains, set in a sparse matrix of very finely divided shell and some secondary calcite (plate 2a and table 1). The shell fragments are randomly oriented except where bedding is strongly developed, in which case they tend to be aligned sub-parallel to the bedding. Locally thin beds, on average 30 mm thick, are internally graded with coarser fragments at the base and finer fragments at the top. The finer-grained portions of such beds are more resistant to weathering, standing out in sharp relief on weathered surfaces. In all instances the acid insoluble residue, which is between 7 and 25% of

PLATE 2a.- Thin section of fresh aeolian calcarenite under plane polarised light x 60. Note elongated shell fragments and high proportion of voids. Shell fragments thinly coated with secondary calcite which acts as a weak cement at the point of contact.

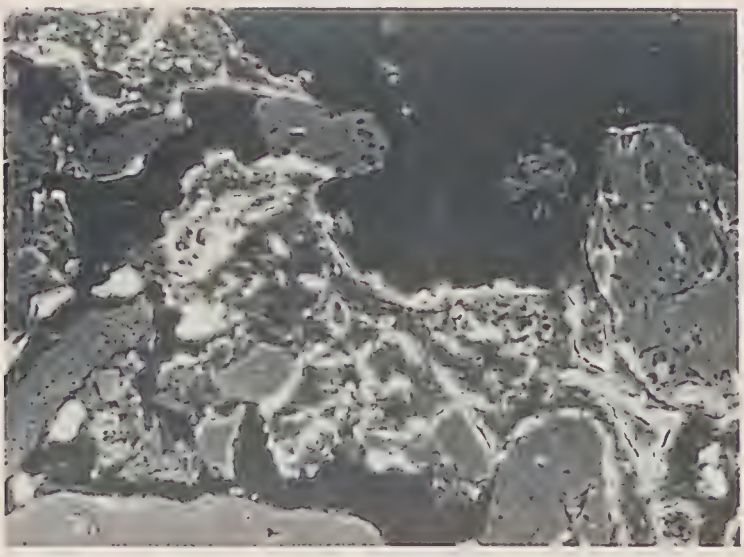

PLATE 2b.- Scanning electron microscope photograph of surface layer of aeolian calcarenite x 100. The poorly laminated cementing medium binding the fragments of shell and quartz (light grey) is gelatinous calcium magnesium sulphate. The homogenous dark grey zones are voids in the rock.

TABLE 1

LOCATION, pH AND CARBONATE CONTENT OF SAMPLES

Sample No.	pH	$\%CaCO_3$	Location
Loose sand			
MCW 6	8.5	14	Surface sample (wet) from against engraved calcarenite panel 13.
MCW 7	8.5	18	Sample from 20 cm below the surface (damp) and against engraved calcarenite panel 13.
MCW 8	7.5	19	Surface sample (wet) 30 cm out from calcarenite panel 13.
MCW 9	7.5	21	Sample from 20 cm below surface sample MCW 8 (damp).
MCW 10	7.0-7.5	21	Surface sample (damp) 4 m seawards of MCW 6 to 9 and on sloping foredune.
MCW 11	7.0-7.5	18	Surface sample from base of foredune (wet) 1 m from fresh high tide strandline.
MCW 13	6.5	11	Surface sample (damp) of sand resting on the top of the cliff.
	7.0-7.5		Surface sand from backbeach within the tidal zone.
	7.0		Sand from 20 cm below the surface at same spot.
	7.5		Terra rosa soil exposed in the gully to the south of the main site.
Aeolian calcarenite			
MCW 14		86	Sample from cliff face to the south of main gallery.
MCW 15		75	Sample from boulder with engraved panel no. 1.
MCW 1969/1		86	Sample collected by Jones from the excavations.
MCW 1969/2		93	Sample collected by Jones from the excavations.

the weight of the rock, consists of fine sand, dominantly well-rounded to subangular frosted quartz. The surfaces of most of the quartz grains are bleached white, but some are iron stained a very pale brown (10 YR 7/3) colour. There are minor amounts of dark coloured minerals and rock fragments, but no siliceous marine organisms.

The rock is highly porous and permeable and its cohesiveness results from the sand-sized grains being embedded in a small amount of finely-divided shell, and partially cemented by secondary calcite. This clear calcite is developed along the interfaces between grains, and is generally less than 0.1 mm in thickness (plate 2a). The cement is not uniformly developed throughout the rock, but occurs randomly, and may reflect the trapping of carbonate-rich fluids from which calcite has subsequently precipitated. Locally but sparsely, secondary calcite is well developed, and the crystals fill pore spaces, strongly binding shell fragments and quartz grains. Because of the sporadic occurrence of the cement binding the grains the rock is potentially susceptible to granular disintegration on pressure of contact. However much of the rock surface is rendered more stable by a dark crust, about 1 mm thick, developed where the rock is directly exposed to subaerial weathering.

Under the microscope the dark surface crust is seen to consist of calcarenite in which the pore spaces are partially filled with a gelatinous inorganic cement which supports a growth of dark algal-like organic material. Scanning electron microscopic examination and IRS analyses of this cement show that it is complex hydrated calcium magnesium sulphate with possibly some dolomite and calcium sulphate (plate 2b). As this sulphate cement is relatively insoluble it accumulates at the surface and the crust so formed provides a protective coating inhibiting granular disintegration of the underlying rock. The cement forms from the reaction between sulphate ions in the sea-spray (based on an analysis of southern ocean seawater by Taylor 1975) and carbonate ions in the shell. In a process similar to dolomitization of aeolianite described by Muller and Tietz (1966), magnesium ions in the sea-spray displace calcium ions released as calcium carbonate dissolves.

On slightly sheltered parts of the cliff the rock surface is pitted as a result of granular disintegration following removal of the calcite cement in solution by groundwater seepage. Within and around some of these pits and along fissures in the rock, a gel-like salt encrustation occurs. This gel is a complex hydrated calcium magnesium sulphate, like the surface cement described above. On drying in the laboratory, the gel crystallises into a hard compact mass. As the drying process is slow and requires low humidity, the formation of a hard cement from this gel probably rarely occurs in the natural environment where the rock remains damp from sea-spray and rain. The partial drying of this gelatinous hydrated calcium magnesium sulphate at the surface of the rock when exposed to the air is taken to be the major cause of the surface hardening noted by Meston (1933) and Jones.

Samples of unconsolidated sand taken from adjacent to the buried engravings and from other localities at varying distances from the rock face (table 1) were analysed (table 2) in order to characterise the sands, to determine whether the loose sand mantle provides an environment conducive to the preservation of the buried engravings, and to assess the extent to which any interaction has occurred between the sand and the rock face.

All the sand samples consisted of well-sorted fine sand with less than 0.5% silt + clay. All comprise predominantly well-rounded quartz grains with varying amounts of recent well-rounded shell fragments, which make up the carbonate content. Sample MCW 9 contained, in addition, some very coarse sand made up of recent shell fragments and fragments of calcarenite. The quartz grains are very slightly to moderately stained with iron oxide, and this imparts a pale to very pale brown (10 YR 6/3-7/3) colour to the sands.

The carbonate in all but one of the samples is composed of low-magnesium calcite. In contrast, sample MCW 7, from adjacent to the buried calcarenite panel 13, contained in

TABLE 2

XRF ANALYSES OF SAND AND CALCARENITE SAMPLES

2a Volatile and sodium-free basis

	MCW6	MCW7	MCW8	MCW9	MCW10	MCW11	MCW13	1969/1	1969/2
SiO_2	86.11	83.99	83.59	83.77	84.61	84.84	89.99	9.58	9.15
TiO_2	0.17	0.18	0.17	0.15	0.19	0.18	0.09	0.09	0.11
Al_2O_3	0.75	0.55	0.58	1.01	2.11	1.27	0.71	1.48	2.40
Fe_2O_3*	0.49	0.43	0.39	0.48	0.48	0.43	0.32	0.53	0.49
MnO	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03
MgO	0.65	0.69	0.66	0.58	0.50	0.49	0.35	1.77	1.68
CaO	11.48	13.88	14.32	13.59	11.78	12.49	8.31	86.02	85.69
K_2O	0.19	0.16	0.17	0.18	0.18	0.16	0.15	0.24	0.21
P_2O_5	0.08	0.06	0.07	0.14	0.08	0.08	0.04	0.14	0.14
S	0.05	0.06	0.06	0.09	0.06	0.05	0.02	0.12	0.09

2b Quartz-free basis [1]

TiO_2	0.58	0.64	0.57	0.51	0.70	0.55	0.60	0.06	0.07
Al_2O_3	2.52	1.97	1.95	2.32	7.79	4.00	4.44	1.04	1.69
Fe_2O_3 *	1.63	1.53	1.30	1.69	1.77	1.36	1.99	0.37	0.35
MnO	0.08	0.04	0.04	0.04	0.04	0.04	0.07	0.02	0.02
MgO	2.17	2.50	2.22	2.05	1.86	1.54	2.19	1.24	1.18
CaO	38.43	50.00	48.52	47.64	43.51	39.27	51.99	60.35	60.39
K_2O	0.66	0.56	0.57	0.63	0.66	0.51	0.93	0.17	0.15
P_2O_5	0.27	0.20	0.23	0.47	0.29	0.26	0.27	0.10	0.10
S	0.16	0.20	0.19	0.31	0.21	0.15	0.13	0.09	0.06
LOSS	53.53	42.39	44.35	44.13	43.13	52.33	37.40	36.61	36.01

* All iron as Fe_2O_3

[1] Loss figure assumes total of 100% (includes CO_2, H_2O, SiO_2, Na_2O and anions)

addition high-magnesium calcite and dolomite. This magnesium is most likely derived from sea-spray, either washed downwards through the sand or percolating through the porous rock and accumulating at the rock/sand interface. Dolomitization of aeolianite by the downward percolation of solutions with a high Mg/Ca ratio in coastal supratidal and spray zones has been described by Adams and Rhodes (1960) and Shinn and Ginsberg (1964). These magnesium-rich compounds are both relatively insoluble and chemically compatible with the calcarenite.

The absence of pieces of calcarenite in the sand samples taken from against the buried rock face (MCW 6 and 7) shows that the buried calcarenite is mechanically stable, and is not undergoing physical disintegration. The gravel-sized fragments of fresh shell and calcarenite in sample MCW 9 were probably incorporated when the engravings were covered with sand in 1971.

The geochemical environment -

The aeolian calcarenite is highly porous and poorly cemented, and consequently friable. However the high porosity and the fact that it consists mainly of calcium carbonate enhance its chemical stability in two ways.

Firstly the close proximity of the site to an exposed coastline means that large quantities of salts from sea-spray are deposited on the site. Such salts, particularly the efflorescent sodium chloride, could cause potentially harmful salt weathering, as in other coastal areas in Australia (Hughes 1978, p.36). However damage from salt weathering is negligible since in this area of high and frequent rainfall, such soluble salts are readily flushed through the porous rock and loose sand cover, and thus removed from the site.

Secondly because the rock contains a high proportion of calcium carbonate, slightly acidic or chemically neutral rainwater quickly becomes alkali-saturated, and ceases to be chemically aggressive.

In addition the geochemical environment of the exposed calcarenite is such that magnesium and sulphate ions in the sea-spray react with the calcium carbonate in the rock to form, especially at the rock surface, a protective insoluble cement, which nevertheless only partially fills the pore spaces.

The fact that the rock is porous, allowing potentially harmful salts to be flushed out, has been a major factor in the survival of the engravings. Any attempt to further stabilise the rock face by the use of surface consolidants would almost certainly result in a considerable reduction in the porosity of the rock surface. This in turn would allow the accumulation of harmful salts, in particular sodium chloride, behind the impregnated rock face, with the ultimate effect of alternate expansion and contraction leading to catastrophic flaking off of the entire consolidated layer. (For a discussion of the use of surface consolidants in the Australian context see Ambrose 1975; Walston 1975; and Walston and Dolanski 1976.)

The cover of loose sand provides a geochemical environment conducive to the survival of the buried engravings, at least in the short term. It can be seen from table 2 that when quartz (SiO_2) is left out of the calculations calcium is the only element which is higher in the buried calcarenite than in the sands. A positive geochemical gradient exists for all other components between the sand and the rock. Loss of components from the calcarenite is inhibited and the rock retains its structure and cohesiveness.

Any loss of calcium by dissolution and leaching of calcium carbonate from the calcarenite is countered by replacement by other components, especially magnesium, and therefore minimal changes will take place within the rock. The mobility of elements between the the rock and its cover of sand is unlikely to be large because of the stabilising influence of a sulphate ion barrier near the rock surface. Because of this barrier, much of the calcium lost from the calcarenite will be precipitated in the sand adjacent to the rock face. Furthermore the accumulation at the rock surface of magnesium-rich

compounds derived from sea-spray also acts to reduce the rate of chemical breakdown of the calcarenite. The pH of the loose sand is higher near the rock face than further from it, indicating that there is in fact some loss of carbonate from the rock into the sand by solution. The accumulation of these alkaline solution products then acts as a buffer, further reducing the rate of solution at the rock surface. For these reasons we consider that the buried blocks of calcarenite should not undergo significant alteration over the next few decades.

An additional beneficial effect of the sand cover is that it protects the engravings from mechanical damage such as gravity induced granular and blocky disintegration of the rock outcrops, sandblasting, trampling by stock and vandalism.

Our conclusion is that although the rock is soft and friable and readily subject to mechanical breakdown if touched, it is not undergoing appreciable weathering through solution of the carbonate, or physical breakdown through salt crystallisation or sand-blasting. Although we take cognisance of reports by earlier workers that many of the engravings are deteriorating rapidly, our examination of a series of photographs of the northern outcrop taken since 1931 (Meston 1933; Luckman 1951b; 1969 photographs supplied by Rhys Jones) indicates that those motifs which are visible at present have undergone no detectable deterioration in this time. This is also largely true of the now-buried motifs, when Luckman's photographs taken in 1949 (Luckman 1951b) are compared with those taken during the 1969 excavations.

Coastal erosion

In contrast to the relatively stable nature of the rock, the site is under considerable continuing long-term threat through coastal erosion. A comprehensive evaluation of this threat is dependent upon an understanding of the history and dynamics of the local shoreline and the blowout adjacent to the site. This is itself a major study, beyond the scope of this report, but the most important geomorphic factors can be broadly identified and their significance evaluated.

The extensive rocky shoreline to the north and the Mount Cameron West headland to the south provide effective barriers to the longshore movement of sand (fig. 1). Thus most of the sand now in the embayment originated through coastal aggradation as the sea approached and attained its present level about 7000 years ago. The equilibrium plan and profile of the beach system, which includes the foredune, beach and the offshore zone affected by wave activity, represent a balance between erosion of the beach and foredune at times of high wave energy, and aggradation at times of relative calm. Sand can be lost from the system either offshore when extreme storm wave activity carries it beyond the influence of the wave zone, or landward beyond the influence of storm waves, by aeolian transport.

The fact that there is an extensive active blowout adjacent to the site means that sand has been, and continues to be lost *permanently* from the beach system. This must inevitably result in the sea encroaching inland in order that the plan and profile of the beach system establish a new equilibrium. We are not able to detail the history of this blowout, but J. Stockton (*pers. comm.*) has examined maps of the region from the 1830s until the 1950s, and comments that whilst large blowouts along the coast are generally marked on such maps, this blowout is not indicated. Since the southern outcrop was almost totally exposed in the early 1930s, it is reasonable to infer that the blowout had already begun developing by that time, although the presence of a scrub cover around the northern outcrop indicates that the northern margin of the blowout had not then encroached to its present position. It seems likely that the blowout began early this century, probably as a result of interference with the vegetation cover through clearance, burning and grazing, but that it remained small until at least the 1940s.

The mean high water limit is within a few metres of the engraving site. During severe storms the presently stable sand cover mantling the engravings could be eroded, or conceivably even be completely removed to expose the engraved rocks to wave erosion. If this coastline were to be affected by exceptionally severe storms in which surges (or

high wave conditions) were also created, such as that which affected much of the New South Wales coastline in May 1974 (Foster *et al.* 1975), catastrophic erosion could easily occur.

DISCUSSION

Provided stock are excluded from the site, shrubby plants with extended root systems are controlled, there is no inherent reason why the rock and its engravings should undergo significant deterioration over the next few decades. This is true of both the exposed and buried rock surfaces. The site should be left covered with a thick layer of sand until a long-term management plan is implemented, as this provides protection from accidental mechanical damage and vandalism.

Measures such as those outlined below are urgently needed to alleviate or prevent coastal erosion.

1. Stabilisation of the foredune system, especially along the front of the blowout. This could be done through planting the presently eroded landforms with marram grass to encourage trapping of windblown sand within the beach system. However given the highly eroded nature of the foredune zone, it is unlikely that such planting will alone prevent the permanent loss of sand inland. A more effective measure would be to build up a foredune artificially, especially at the northern end, and plant this constructed dune with marram grass, to ensure that sand is trapped more efficiently in the beach system. It is *essential* that the sand used for this purpose be taken from the inland dunes, and *not* from the beach itself.
2. To minimise storm wave damage to the site itself, the blanket of sand mantling the engravings should be maintained, and preferably extended, also using sand brought from inland, and *not* from the adjacent beach. We note that Garry Melville has effectively stabilised the existing sand blanket and has erected a fence to keep out stock, and these measures have provided a sound basis for further management of the site.
3. Measures 1 and 2 will not be effective against exceptionally severe storms, and in the long-term (provided the site has not already been damaged in the meantime) the continued existence of the site can only be ensured through the construction of major coastal protection works along the beach, immediately in front of the site. Such construction works, which would be costly, would first require a major study of the coastal dynamics of the embayment. It is likely that such works would result in considerable changes in the longshore plan of the beach, especially to the south.

CONCLUSION

Ultimately the Service intends to prepare a long-term management plan involving conservation, presentation and interpretation of the site. Our conclusions on the geochemical environment of the engraving site, based as they are on limited fieldwork and analyses, may not provide an adequate basis for long-term site-specific management decisions. Before any management programme is implemented, for example possible re-excavation of the buried engravings for display, enclosure of the site in a protective shelter etc., more comprehensive and detailed studies of the calcarenite and its geochemical and hydrologic environment may be necessary. Coastal erosion control measures will have to be implemented as a first step in any management plan. Although some of these measures can be applied immediately, before a comprehensive erosion control programme can be designed a detailed study of the history and morphodynamics of the embayment will be necessary

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University, provided historical data and Winifred Mumford, of that department, drew the figure. SRD, IRS and XRF analyses were carried out in the Geology Department, Australian National University.

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The Council places on record his long and dedicated survice to the Society.

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ROYAL SOCIETY OF TASMANIA

ANNUAL REPORT FOR THE YEAR 1981

The Council has the honour to present to members the following report on the activities of the Society during the year.

COUNCIL AND OFFICE BEARERS

Patron

Her Majesty the Queen

President

His Excellency the Governor of Tasmania
Sir Stanley Burbury

Vice-Presidents

Mr D.R. Gregg Dr A.G. Wallace

Council

Miss Roberta Barnett
Dr E.A. Colhoun
Mr R.J. Downie
Mr E.H. Fist
Mr I.D. Geard
Mr G.E.A. Hale
Dr Jocelyn Townrow
Mr L.E. Wall
Mr R.E. Ward

Honorary Secretary
Mr D.R. Gregg

Honorary Treasurer
Mr T.A.H. Knight

Honorary Auditor
Mr D.B. Churchill

Honorary Editor
Dr M.R. Banks

WILLIAM EDWARD LODEWYK HAMILTON CROWTHER

Sir William Crowther CBE, DSO, VC, MB, BS, FRACP died in Hobart on 31 May 1981, aged 94.

Sir William joined the Society in 1911 and was elected an Honorary Life Member in 1962. He received the Royal Society of Tasmania Medal in 1940 for his contributions to Tasmanian ethnology. He served as the Society's representative on the Trustees of the Tasmanian Museum from 1919 until 1939. He then continued on the Trustees as an appointee of the Governor until his retirement in 1973. His service as a Trustee ran continuously for over 54 years.

The Council places on record his long and dedicated survice to the Society.

HONORARY LIFE MEMBER

Mr K.E.J. Robinson was elected an Honorary Life Member in recognition of his dedicated service to the Society since he joined in 1964. He has served on the Council of the Northern Branch almost continuously since 1967 and was Vice-President of the Society in 1976-77 and a member of the Council from 1971 to 1980.

ANNUAL MEETING

At the Annual Meeting on 3 March, Mr R.J. Downie retired as Vice-President and Mr K.E.J. Robinson as a Member of the Council. The following were elected:

Vice President	Dr A.G. Wallace
Members of Council	Miss Roberta Barnett
	Mr I.D. Geard
Honorary Secretary	Mr D.R. Gregg
Honorary Treasurer	Mr T.A.H. Knight
Honorary Auditor	Mr D.B. Churchill

REVIEW OF RULES

The changes to the Rules, proposed by the Council, were adopted at the 1981 Annual General Meeting.

MEMBERSHIP

The membership is 470, a decrease of 1, and is made up as follows:

	Northern Branch	Total
Honorary Life Members	2	8
Life Members	8	36
Ordinary Members receiving the Papers and Proceedings	63	260
Ordinary Members not receiving the Papers and Proceedings	80	146
Associate Members	17	20
	170	470

COUNCIL MEETINGS

The Council met four times during the year, with Mr R.E. Ward and Mr E.H. Fist representing the Northern Branch on the Council. A meeting was held in Launceston on 11 December 1981.

BANKS MEMORIAL LECTURE

The Council has continued to pursue the proposal that the bicentennial of the European settlement of Australia in 1988 be marked by a lecture honouring Sir Joseph Banks.

PUBLICATIONS

Volume 115 of the Papers and Proceedings was published in September 1981. It contained 18 papers by 31 authors and totalled 225 pages. The volume included a three-page "Instructions to Authors".

The Society is once more indebted to Dr Banks for his dedicated and skilled work as Honorary Editor.

LIBRARY

The Library has continued to function smoothly during the year under the direction of the Librarian, Mrs Mary Marshall.

Steady use of the Library continues and during the year 430 visits by Society members University staff and students and other users were recorded in the Register. The Library also supplied 214 items in response to interlibrary loan requests. The University Bindery maintained its high rate of output and approximately 1 750 volumes of Royal Society periodicals were bound during the year.

The reshelving of the serials collection was completed towards the end of the year and the interfiling of quarto and octavo volumes into one sequence has made location of individual titles easier without any reduction of shelf space. Monographs continue to be differentiated according to size.

A continuing surplus of back issues of Society publications necessitated another sale (the first sale was held during 1979) which was most successful. It was decided that stocks of Papers and Proceedings be reduced to 20 for pre-1970 issues and 50 for 1970-79 issues. Surplus issues of the earlier volumes were soon exhausted, and stocks of later volumes considerably reduced. In addition, many full-priced publications were sold and the congestion in storage areas somewhat relieved.

Council during the year decided that in future sales of Society publications and distribution of Papers and Proceedings to members will no longer be handled by the Librarian, but conducted from the Tasmanian Museum by a part-time clerical assistant. The Library will continue to handle the organisation and despatch of exchange copies of Papers and Proceedings for which it receives hundreds of publications gratis from institutions throughout the world. In October 236 copies of the latest volume of Papers and Proceedings were mailed to overseas partners and 55 copies to Australian partners.

Two new exchanges were finalized during the year. The new serial titles received are: Koedoe (National Parks, Pretoria, South Africa), and Willdenowia (Botanischer Garten u. Botanischer Museum, Berlin).

From 30 March 1981, the Librarian commenced fractional time employment, working four days per week - Monday, Tuesday, Thursday, and Friday. On Wednesdays the Library is staffed by a part-time clerical assistant, Mrs P. Wendell-Smith.

An agreement was concluded between the Tasmanian Library Board and the Council of the Society dealing with the housing at the Northern Regional Library of that part of the Library of the Society held in Launceston.

LECTURES

The following lectures were given at General Meetings during the year:

March	"Sundown Creek: a case study in Tasmanian prehistory."	Mr Don Ransom, National Parks and Wildlife Service
April	"The mosses and liverworts of the Mount Wellington Range."	Dr D.A. Ratkowsky, C.S.I.R.O.
May	"Some history of Tasmanian road bridges."	Sir Allan Knight
June	"Small things amuse ... the big world of the microfossil."	Dr P.G. Quilty, Antarctic Division Department of Science and Technology

July	"The history of the Royal Tasmanian Botanical Gardens."	Mr Marcus Hurburgh, Royal Tasmanian Botanical Gardens
August	"The approach to 1984 - computing technology."	Professor A.H.J. Sale, University of Tasmania
September	"The weather map."	Mr E.F. Phillips, Bureau of Meteorology Department of Science and Technology
October	"Is cancer curable?"	Dr R.M. Lowenthal, University of Tasmania
November	"Tasmanian owls."	Mr L.E. Wall

NORTHERN BRANCH

Chairman	Mr D. Walter
Vice-Chairman	Mr B.A. Pike
Past Chairman	Mr H.S. Payne
Council Members	Mrs S.M. Dent
	Mr D.H. Fist
	Mr D.G. Hannan
	Mr T.M. Tatlock-Goodrick
	Mr R.E. Ward
Honorary Secretary	Mr P.G. Webb
Honorary Treasurer	Mr K.E.J. Robinson
Honorary Auditor	Mr J.D.A. Abey
Representatives of Branch on Council	Mr R.E. Ward
	Mr E.H. Fist

The Branch Council met five times, the principal business other than routine matters being consideration of the proposed amendments to the Rules of the Society with a view to incorporating a set of rules for the operation of the Branch. Two proposals for publications were discussed, and one of these will be undertaken, the other is still under consideration.

The following lectures were given at General Meetings:

March	"Romania since World War II."	Mr T.R. McGlynn
April	"James MacLanachan, an early settler in Tasmania."	Mr Geoff O'Brien
May	"To plan, or not to plan - in politics and administration."	Mr J. Chambers
June	"The river edges of Launceston."	Mr D. Goldsworthy
July	"The background to hearing of impaired children, and some glimpses into the near future."	Mr J. Thorne
August	"Protection from floods - the Launceston story: from fear to confidence."	Mr G. Burrows
September	"The Senate Report on transport to and from Tasmania."	Senator P. Rae
October	"Architecture; where is it going?"	Mr B. Shelton
November	"Western Tasmania: a study in historical geography."	Mr C. Binks

December	Members' Night -	"Liliums."	Mrs J. Ward
		"Treasures of the tip."	Mr P.F.J. Leonard
		"Britain by Britrail."	Mr P.G. Webb
		"Fanlights."	Mr A.T. Orr.

A one-day excursion to Campbelltown was led by Mr Geoff O'Brien. Members had the opportunity to examine many of Mr O'Brien's items of interest, and to explore the town.

Two bulletins were issued for sale to members: "Romania since World War II" and "To plan or not to plan, in politics and administration". A third, "West Coast explorers", will be available early in 1982.

NOMINEES TO OTHER BODIES

The Council elected Dr M.R. Banks and Mr A.R. Neilson to the Board of Trustees of the Tasmanian Museum and Art Gallery. Dr Donald Martin resigned from the Board in February 1981 having served as the Society's appointee since 1970. They report on the year's activities:

> The 1981 State Budget was a little more generous to the Tasmanian Museum and Art Gallery than that of the previous year. The Government grant of $700 000 was an apparent increase of 11%, but, because of one extra pay day in the 1981-82 year, was an actual increase of only 8%. No grant was made for capital works, and renovations, which stopped in August 1980, on the partly completed Commissariat Store buildings at 40 Macquarie Street have not been resumed.
>
> Very stringent control has been kept on expenditure during the year. The Trustees, with the full cooperation of the staff, have exercised strict economies which have ensured that the Museum and Art Gallery continued to provide a service to the public during the year, even if this was at a reduced level of activity. The Trustees are concerned that any further continuation of these economies may prejudice the viability of the Museum and Art Gallery as as active and developing institution.
>
> It should be pointed out that the expenditure of the Tasmanian Government on museums and art galleries is significantly below the assessed needs as established by the Commonwealth Grants Commission in its "Report on State Tax Sharing Entitlements 1981".
>
> During 1981, visitors to the Tasmanian Museum and Art Gallery totalled 120 537, compared with 130 791 for 1980. The higher figure for 1980 was due to the popularity of the "Century of Modern Masters" exhibition. The attendance at the West Coast Pioneers' Memorial Museum at Zeehan was estimated at 130 000 for the 1980-81 financial year.
>
> Dr Banks was re-elected Chairman of Trustees.

Dr Jocelyn Townrow continued as the Council's nominee on the Board of Trustees of the Royal Tasmanian Botanical Gardens. She reports on the year's activities:

> The improved standards in the Gardens have been maintained with difficulty and replacement of the depot area and No.4 glasshouse has been deferred yet again, because of lack of Government funding. However, the State Government Budget allocation for 1981-82 of $675 000 included a special grant of $80 000 towards provision of new public toilet and sewerage facilities, to be funded over several years. A balanced budget was achieved by working on less than a full complement of employees and by deferring important work, such as maintenance of buildings, roads and paths, and construction of a retaining wall. Funding permitted the employment of 30 persons only, instead of a full complement of

35 persons and as a consequence, work at the Gardens, Parliament House and the Supreme Court was not undertaken as fully as Trustees would have liked.

Mr John Howell, appointed to the Board in 1965, and Chairman since 1969, resigned at the end of June. His dedicated service is acknowledged with gratitude by the Board; Mr Geoff Fader replaces him as Chairman. New members on the Board of Trustees are Mr J.B.G. Hulton, who replaces Commander G.B. Campbell, and Mr I.D. Geard replacing Mr Howell, both being ministerial appointees.

The Superintendent, Mr May, returned from his Churchill Fellowship tour of Europe, U.K. and U.S.A. with a wealth of new ideas for implementation in our Gardens.

Mr Marcus Hurburgh, at one time the Royal Society's representative on the Board and presently the Garden's Information and Education Officer, is resigning after three years service. He is being replaced by Mr Alan Gray whose appointment commences in January 1982.

Major developments in the Gardens include the "Easy Access Garden" (formerly referred to as the "Garden for the Disabled") next to the Museum and Education Centre, and the new fernery and waterfalls on the south side of the lily ponds. The Easy Access Garden, financed by the Lindisfarne Lions Club ($6 000) and the State Government ($8 000), is well advanced with foundations, beds and paths completed. Special toilet facilities, a glasshouse and shelter are in the planning stage. Funding for these additions is being sought through donations, which so far total $2 700. A plant sale and raffle organised by the Superintendent raised a further $6 000. The new fernery is a most attractive addition and is planted out largely with native and/or endemic species.

Further excavation work has been carried out on the Aboriginal midden site and methods for stabilising the excavated face are under investigation, prior to the development of the site as a valuable new feature at the northern end of the Gardens.

The Museum and Education Centre has attracted much favourable comment this year and has been visited by 19 652 persons representing 11.7% of total visitors to the Gardens. It has been a very popular venue for School excursions with visits by 1 449 children and 164 teachers from 40 schools. The Museum now houses the very valuable working herbarium of the Society for Growing Australian Plants.

Total visitors to the Gardens were some 7 000 down on 1980 (168 142) and this reflects the poor weather conditions experienced in January, February, June, July and August.

ACKNOWLEDGEMENTS

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, and the Queen Victoria Museum and Art Gallery are specially thanked for their help and cooperation.

The Honorary Secretary and Senior Vice-President is especially grateful for the help given by other members of Council during the time he has held these two offices.

ROYAL SOCIETY OF TASMANIA

STATEMENTS OF RECEIPTS AND PAYMENTS
FOR THE YEAR ENDED 31 DECEMBER 1981

GENERAL ACCOUNT

Balance brought forward		1 343.59	Stationery	352.87
			Insurance	137.03
Subscriptions			Attendant's fees	444.24
			Secretarial fees	416.50
240 @ $12	2 880.00		Management fee	725.00
141 @ $8	1 128.00		Post box rental	109.00
18 @ $5	90.00		Postage and freight	828.01
Other years	117.00		Investments - Lewis	400.00
			Photocopying	289.28
		4 215.00	Subscriptions	595.16
			Northern Branch	1 100.00
Interest		1 398.82	Repairs and maintenance	35.00
Government grant		1 450.00	Stamp duty	10.00
Rent		370.64	Miscellaneous	12.80
Miscellaneous		42.50		
Redeemed investments - Lewis		400.00		
Sales of publications and			Typing of Papers and	
Papers and Proceedings		2 114.14	Proceedings	1 152.00
				6 606.89
			Balance carried forward	4 727.80
		$11 334.69		$11 334.69

PAPERS AND PROCEEDINGS ACCOUNT

Balance brought forward	3 135.37		
Interest	965.65	Balance carried forward	4 101.02
	$4 101.02		$4 101.02

ACCUMULATION ACCOUNT

Balance 1 January 1981			54 490.94
Deduct: Net transfers to Trust Funds		887.65	
Net decrease in valuation of publications for sale		8 724.65	9 612.30
			$44 878.64
Add: Net decrease in advance subscriptions		51.00	
Increased cash at bank		4 509.84	4 560.84
Balance 31 December 1981			$49 439.48

ROYAL SOCIETY OF TASMANIA

AUDITED BALANCE SHEET AS AT 31 DECEMBER 1981

1980			1981	1980		1981
54 470.94	Accumulated funds		49 439.49	33.00	Cash on hand	33.00
100.00	Subscriptions in advance		49.00		Cash at bank:	
	Trust Funds:			1 343.59	- General Account	4 727.80
1 352.14	- Clive Lord Memorial Fund	1 429.68		3 135.37	- Papers & Proceedings Account	4 101.02
2 208.70	- A.N. Lewis Memorial Fund	2 353.14		713.45	- Clive Lord Memorial Fund	773.49
980.29	- Morton Allport Memorial	1 053.42		1 198.84	- A.N. Lewis Memorial Fund	1 318.78
411.27	- A.A. Clark Bequest	438.73		860.00	Mortgage loan	860.00
2 753.90	- Joseph Milligan Bequest	2 933.52			Commonwealth Treasury Bonds	
1 435.86	- R.M. Johnston Memorial Fund	1 544.59		14 440.00	& Inscribed Stock (at cost)	14 440.00
634.32	- Henry Oliver Bequest	683.26		7 000.00	Interest Bearing Deposits	7 000.00
1 493.13	- W.H. Hudspeth Memorial	1 581.07		15 000.00	Library (at valuation for insurance)	15 000.00
2 273.70	- Life Membership Fund	2 413.55	14 430.96	24 390.00	Publications (at selling prices)	15 665.35
$68 114.25			$63 919.44	$68 114.25		$63 919.44

Papers and Proceedings of the Royal Society of Tasmania, Volume 116, 1982

(ms. received 22.1.1982)

A PYGMY RIGHT WHALE *CAPEREA MARGINATA* (GRAY, 1846) STRANDED AT STANLEY, TASMANIA

by B.L. Munday, R.H. Green and D.L. Obendorf
Mt Pleasant Laboratories, Department of Agriculture
Launceston South (B.L.M. and D.L.O.) and
Queen Victoria Museum and Art Gallery, Launceston

(with one plate and one table)

ABSTRACT

MUNDAY, B.L. GREEN, R.H. and OBENDORF, D.L., 1982 (31 viii): A pygmy right whale *Caperea marginata* (Grey, 1846) stranded at Stanley, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 1-4. ISSN 0080-4703. Department of Agriculture, Launceston South and Queen Victoria Museum and Art Gallery, Launceston, Tasmania.

A pregnant female pygmy right whale, *Caperea marginata* (Gray, 1846) which stranded at West Beach, Stanley was examined within 24 hours of stranding. No significant pathological condition was detected in the carcase thus eliminating disease as the likely cause of stranding. However, the area is a notorious "whale trap", and it is therefore assumed that geographical and hydrological conditions accounted for the stranding. A number of interesting anatomical features are noted.

INTRODUCTION

On 10th September 1981 a female pygmy right whale *Caperea marginata* (Gray, 1846) was reported to have been stranded on West Beach, Stanley. Though dead, it was in fresh condition and had apparently come ashore the previous night. On the following morning, two pathologists, one from Mt Pleasant Laboratories and one visiting from the Ontario Veterinary College, Canada, drove to the site to examine the whale, gather data and obtain specimens for further investigation.

West Beach is on the western side of the Stanley Peninsula facing Perkins Bay, a shallow, semi-enclosed stretch of water with a sandy bottom. Owing to the topography, the tide can recede up to half a kilometre.

OBSERVATIONS

The whale was found to be lying on its left side and facing north (parallel to the beach). It had raw ulcers on the right mandible and recently healed ulcers above the right eye. There were numerous healed lesions overall and a bleeding wound posterior to the genital aperture. Dimensions of the whale are given in table I.

Upon dissection, the whale was found to be pregnant, carrying a female foetus of 600 gm and of a total length of 0.38 m. This foetus had a relatively well-developed head with a prominent mouth but lacked any indication of baleen development. The auditory meatus was barely discernible as a pin-prick indentation, the blowhole was open and the eyes just open as a 5 mm slit across the lower half of the eyeball. The entire skin (after preservation) was a pale cream with some pale grey subcutaneous shading. The presumed corpus luteum of pregnancy was present in the left ovary, which also had at least 14 corpora albicantes and 24 follicles up to 20 mm in diameter. The right ovary supported at least 31 follicles of up to 25 x 40 mm and 11 corpora albicantes. No milk was present in the mammary gland. The placenta was villous epitheliochorial in structure.

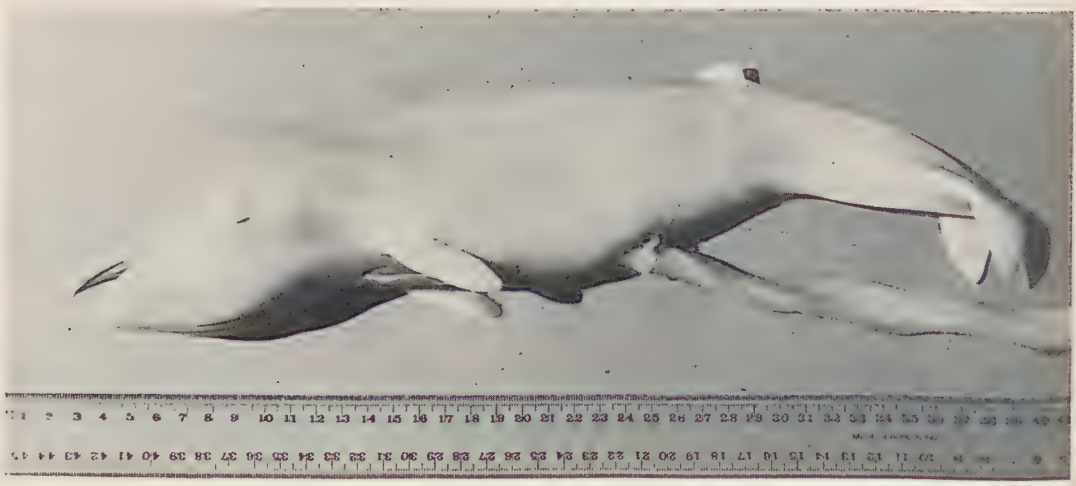

PLATE 1.- The female foetus which was taken from a pigmy right whale stranded at West Beach, Stanley, on 10th September 1981.

The larynx was surrounded by spongy tissues which communicated freely with both the oropharynx and the larynx itself. These tissues consisted of a connective tissue matrix permeated by channels lined by tall columnar epithelium and interspersed with areas of mucus-secreting glands. The ventral aspect of the larynx opened into a large diverticulum, which had a honeycombed internal surface lined by glandular epithelium and was surrounded by a thick muscular wall.

The stomach consisted of four distinct compartments. The first, and largest, was a simple diverticulum lined by non-glandular squamous epithelium. The tubiform second compartment was lined by mucus-secreting epithelium approximately 7.5 mm thick. Fundic (acid- and enzyme-secreting cells) glands lined the surface of the third compartment which had an epithelium approximately 15 mm thick. This organ was elongated with numerous transverse rugae on its mucosal surface. The fourth "stomach" was the smallest compartment. It was globose with a smooth glandular lining and was the point of entry of the single bile duct. This organ contained bile-coloured fluid and an "ambergris" soft-stone approximately 40 mm in diameter.

The caecum was 0.5 m long and had no taenia. Trematodes 7-8 mm in length were present in this organ and the proximal colon.

The head was removed and lodged with the Queen Victoria Museum for skull preparation (Reg. No. 1981/1/165). The foetus (Reg. No. 1981/1/166) and ovaries (Reg. No. 1981/1/167) have been preserved in 4% formalin and also lodged with that museum.

DISCUSSION

Previous reports of pygmy right whale strandings in Tasmania are limited. Davies and Guiler (1957) and Guiler (1978) presented results of their investigations into pygmy right whale strandings, including a number from Tasmanian waters, and provide some photographs of an adult female at Ralphs Bay on 23rd June 1956.

Guiler (1961) recorded "the first evidence of breeding in this species" following his examination of a female (total length 6.37 m) stranded at Eaglehawk Neck on the night of 26th June 1961. That specimen was carrying a foetus of 3 kg and of a total length of 0.6 m (lodged in the collections of the Zoology Department, University of Tasmania) and was thus five times the body weight and twice the total length of our Stanley foetus. As our specimen was collected about 11 weeks later (seasonally) it appears that breeding in this species is not confined to a restricted season.

It is commonly asserted "that in the case of single strandings", the animal is generally in an advanced state of disease" (Bergin 1978). This was not the case with the pygmy right whale stranded at Stanley which was suffering from no detectable disease and carried very few parasites. It is more likely that the animal became disorientated in unfamiliar territory where sonar navigation could be impeded by the very gradual slope of the bottom. Indeed, strong northwesterly winds, such as those occurring at the time, could be expected to back up water to the beach at high tide leading to completely erroneous feed-back from the animal's sonar soundings.

ACKNOWLEDGEMENTS

The authors wish to express their thanks for the assistance of Mr Robin King, National Parks and Wildlife Service, who reported the stranding and assisted with the on-site examination. Valuable assistance was also rendered by Dr I.K. Barker and Mr T. Black.

REFERENCES

Bergin, T.J., 1978: Stranded whales and dolphins. *Proceedings No.36 of Courses for Veterinarians.* The Post-Graduate Committee in Veterinary Science: 585-595.

Davies, J.L. and Guiler, E.R., 1957: A note on the pygmy right whale *Caperea marginata* Gray. *Proc. zool. Soc. Lond.*, 129: 579-589.

Guiler, E.R., 1961: A pregnant pygmy right whale. *Aust. J. Sci.*, 24: 297.

_____ , 1978: Whale strandings in Tasmania since 1945 with notes on some seal reports. *Pap. Proc. R. Soc. Tasm.*, 112: 189-213.

Norris, K.S., 1961: Standardised methods of measuring and recording data of the small cetaceans. *J. Mamm.*, 42: 471-476.

ADDENDUM

Another pregnant, pygmy right whale stranded at West Inlet, Perkins Bay, on 15.6.82. It is believed that this 6 metre animal came ashore on a very high tide the previous evening. This animal carried a foetus approximately two metres in length, further indicating that breeding is not confined to a restricted season.

TABLE I

Measurements (mm) of a specimen of a female pygmy right whale stranded at West Beach, Stanley. The index numbers and dimensions are after Norris (1961).

Index Number	Feature	Dimension
1	Length to fluke notch	6450
2	Length to mid-eye	1280
4	Length to gape	1040
5	Length to auditory meatus	1060
6	Mid-eye to auditory meatus	380
7	Mid-eye to angle of gape	220
8	Mid-eye to mid-blowhole	870
9	Head length to blowhole	900
10	Length to pectoral	1890
11	Length to tip of dorsal fin	4610
12	Length to mid-umbilicus	3470
13	Length to mid-genital slit	4700
14	Length to mid-anus	4920
15	Projection of lower jaw	180
17	Blubber thickness at mid-dorsum	60
18	Blubber thickness at mid-lateral	20
19	Blubber thickness at mid-ventrum	40
21	Half girth at axilla	1840
23	Half girth at anus	1210
24	Length of eye	50
25	Length of right mammary slit	120
	length of left mammary slit	90
26	Length of genital slit	690
27	Width of blowhole	110
	Length of blowhole	200
28	External auditory meatus	30x10
29	Length of pectoral, anterior	760
30	Length of pectoral, posterior	470
31	Width of pectoral, maximum	200
32	Height of dorsal fin	300
33	Length of dorsal fin base	440
34	Width of flukes	2000
35	Anterior of fluke to notch	480
36	Depth of notch	90

Papers and Proceedings of the Royal Society of Tasmania, Volume 116, 1982.

(ms. received 26.5.1981)

TASMANIAN TERTIARY FORAMINIFERIDA. PART 3.

DISCORBACEA (EPONIDIDAE) TO NONIONACEA

by Patrick G. Quilty
Antarctic Division, Kingston, Tasmania
(formerly Macquarie University)

(with three text-figures and six plates)

ABSTRACT

QUILTY, P.G., 1982 (31 viii): Tasmanian Tertiary Foraminiferida. Part 3. Discorbacea (Eponididae) to Nonionacea. *Pap. Proc. R. Soc. Tasm.*, 116: 5-51. ISSN 0080-4703. Antarctic Division, Department of Science, Kingston, Tasmania.

This final part recording the Tasmanian Tertiary benthonic Foraminiferida documents the occurrence of 77 taxa of which 65 are previously defined, four are compared with previously defined species and eight are identified generically only. No species are new. Five forms recorded in parts 1 and 2 are noted from a newly discovered sample from Welcome River.

INTRODUCTION

This is the third part of a series of papers in this journal designed to document the Oligo-Miocene Foraminiferida of Tasmania and completes discussion of the benthic forms. The previous papers are those by Quilty (1974, 1977) and the conventions of occurrence are common to the three papers and are explained in Quilty (1974). Several new forms were described by Quilty (1980) are are simply recorded here. The stratigraphic framework of the Tasmanian Tertiary marine rocks was explained in Quilty (1972).

The classification of the Foraminiferida followed here is the same as in Quilty (1977) and is that proposed by Loeblich and Tappan (1974). Ages are quoted in terms of the N zones of Blow (1969). Occurrences are listed approximately from oldest to youngest.

Since the last of the series was published, another locality has been sampled and has yielded an interesting foraminiferid fauna. The locality is near the mouth of the Welcome River (figure 1) and was sampled by Mr G. van der Geer of the Geography Department, University of Tasmania. The rock specimen is catalogued in the collections of the Geology Department, University of Tasmania (UTGD) under the catalogue number UTGD 45979. The rock consists of a friable partly recrystallised bryozoal calcarenite. Preservation is quite good.

Several species from this new fauna are relevant to parts 1 and 2 of this series. They are:

Textularia gramen d'Orbigny (r); *Gaudryina convexa* (Karrer) (r); *Heronallenia lingulata* (Burrows & Holland) (r); *Glabratella crassa* Dorreen (r); *Pileolina* sp. indet. (r).

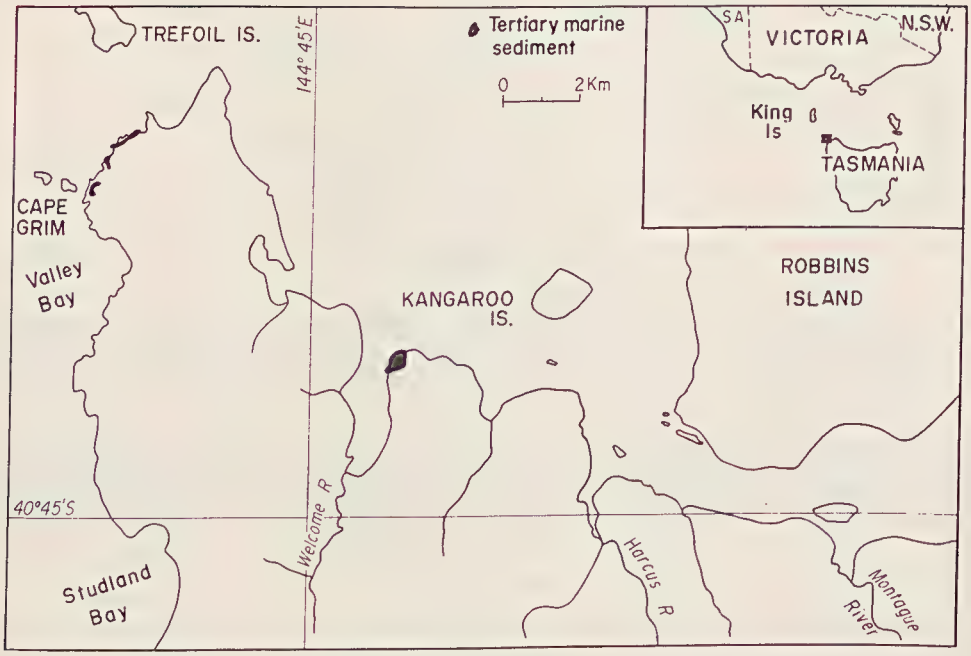

FIG. 1 - The location of Tertiary marine sediments at Welcome River.

SYSTEMATICS

Order FORAMINIFERIDA
Suborder ROTALIINA
Superfamily DISCORBACEA
Family EPONIDIDAE
Genus *EPONIDES* de Montfort, 1808
Eponides lornensis Finlay, 1939
(Pl.1, figs 1,2)

Eponides lornensis Finlay, 1939a, pp.521,522.
E. lornensis Finlay 1939, *Trans. R. Soc. N.Z.* (69(1): 121, pl.13, figs 52,53.
E. lornensis; Carter 1958, p.44, pl.5, figs 48-50.
E. lornensis; Hornibrook 1961, p.109, pl.15, figs 323,325.

Type locality and stratigraphic level - 0.5 km NW of Lorne Railway Station, New Zealand; Late Eocene.

The specimens found in the Great Musselroe Bay sample are much more typical of Finlay's (1939) figures than is the specimen figured by Carter (1958). Some quite irregular forms are found with a much more open umbilicus than Carter figured. The form is here regarded as a variant of, intergrading with, and often not separable from *E. repandus*. It is considered ancestral to *E. repandus* although as a morphotype, *E. repandus* is found as far back in time as the Late Eocene.

Occurrence: Great Musselroe Bay - 84483 (r).
Age: Late Oligocene, N3.

Eponides repandus (Fichtel and Moll), 1798.
(pl.1, figs 3,4)

Nautilus repandus Fichtel and Moll, 1798: *TESTACEA MICROSCOPICA* ..., (Camesina: Vienna) 35, pl.3, figs a-d.
Pulvinulina repanda (Fichtel and Moll); Howchin 1889, p.14.
P. repanda; Howchin 1891, p.353.
P. repanda; Heron-Allen and Earland 1924: *J. R. microscop. Soc.* (1924): 179.
Eponides repandus (Fichtel and Moll); Chapman, Parr and Collins 1934, p.565, pl.9, fig.18.
E. repandus; Crespin 1943, p.79.
E. repandus; Carter 1958, pp.45,46, pl.6, figs 51-53.
E. repandus; Ludbrook 1961, p.57 *et seq.*, pl.2, figs 6,7.
E. repandus; Carter 1964, p.83, pl.4, fig.86.
E. repandus; Reed 1965, p.78.

Type locality and stratigraphic level - Mediterranean Sea; Holocene.

This species is very widespread, being found in all sections except Fossil Bluff. It is well preserved only in the Great Musselroe Bay samples. In the few complete specimens, no pores could be seen on the apertural face. Several Great Musselroe Bay specimens can be referred to *E. lornensis* Finlay, and it seems that the two species are intergradational as suggested by Hornibrook (1961) rather than conspecific, a belief apparently held by Reed (1965). Intergradational species would be separated into a population with a high proportion of *E. lornensis* Finlay which would be older (Eocene-Oligocene) than another population with a higher proportion of *E. repandus* (F. and M.). The forms are separated here, although regarded as intergradational.

Occurrence: (a) Great Musselroe Bay - 84483(f), 84481(f), 84482(r); (b) King Island - 84084(q), 84085(r), 84081(r), 84082(r), 84083(f), 84086(a), 84089(p), 84475(q), 84476(q), 84477(q); (c) Daisy Creek - 84478(r); (d) Cape Grim - 84006(v); (e) Mt Cameron West - 84121(v), 84120(v), 84117(c); (f) Preservation Island - 84479(q); (g) Brittons Swamp - 84480(r); (h) Redpa - 84097(r), 84093(q), 84094(r), 84095(q), 84096(r); (i) Cape Barren Island - 84554(f); (j) Marrawah district - 84561(r), 84109(r), 84110(r), 84111(r), 84113(q), 84114(q), 84104(v), 84101(r), 84106(r), 84107(q).

Age: Late Oligocene-Early Miocene, N3-N8.

Family SIPHONINIDAE
Genus *SIPHONINA* Reuss, 1850
Siphonina australis Cushman, 1927
(Pl.1, fig.5)

Siphonina australis Cushman, 1927: *Proc. U.S. natn. Mus.* 77, art.20: 8,9,pl.2, figs 6a-c; pl.3, figs 7a-c, 8a-c.
S. australis; Chapman, Parr and Collins 1934, p.567, pl.10, figs 23a-c.
S. australis; Crespin 1943, p.83.
S. australis; Carter 1964, p.93, pl.7, figs 127-129.
S. australis, Reed 1965, p.69.

Type locality and stratigraphic level - lower beds at Muddy Creek, Victoria; Middle Miocene.

Occurrence: (a) Great Musselroe Bay - 84483(v), 84481(v), 84482(v); (b) Fossil Bluff - 84010a(v), 84010b(r), 84011(q), 84013(v), 84014(r), 84017(r), 84019(v), 84025a (v), 84025b(v); (c) Cape Grim - 84008(v), 84006(r), 84005(v), 84001(v); (d) Mt Cameron West - 84118(f), 84121(r), 84120(f); (e) Marrawah district -

84092(v), 84561(q), 84104(r), 84101(r), 84105(v), 84106(r), 84107(q).

Age: Late Oligocene-Early Miocene, N3-N8.

Family AMPHISTEGINIDAE
Genus *AMPHISTEGINA* d'Orbigny, 1826
Amphistegina lessonii d'Orbigny, 1826
(Pl.1, figs 6,7)

Amphistegina lessonii d'Orbigny, 1826: *Annls Sci. nat.* ser.1, 7: 304, pl.17, figs 1.4.
A. lessonii; Howchin 1889, p.16.
A. lessonii; Chapman, 1910: *Proc. R. Soc. Vict.* n.s., 22: 294, pl.53, fig.6.
A. lessonii; Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924), pt.2: 185.
A. lessonii; Chapman, Parr and Collins 1934, p.568, pl.10, figs 25a-c.
A. lessonii; Crespin 1936, pl.1, fig.9.
A. hauerina; Howchin and Parr, 1938: *Trans. R. Soc. S. Aust.* 62 (2): 311, pl.18, fig.1.
A. hauerina; Parr, 1939: *Min. geol. J.* 1 (4): 69.
A. lessonii; Crespin 1943, p.77.
A. "lessonii"; Ludbrook 1961, p.87 *et seq.*, pl.4, fig.1.
A. lessonii; Carter 1964, p.115, pl.11, figs 223-225.
A. lessonii; Cooper, 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.3.

Type locality and stratigraphic level - Mauritius; Holocene.

The species listed above in the synonomy quite clearly refer to the species found here. Carter (1964) has given reasons for believing it to be *A. lessonii* and he is followed here.

Occurrence: (a) Preservation Island - 84479(a); (b) Brittons Swamp - 84480(c); (c) Cape Barren Island - 84554(r); (d) Marrawah district - 84113(f), 84114(f), 84115 (a), 84104(f), 84101(c).
Age: Early Miocene.

Family CIBICIDIDAE
Subfamily PLANULININAE
Genus *HYALINEA* Hofker, 1951
Hyalinea sp.
(Pl.1, figs 8,9)

A single specimen from King Island [84084(v)] is tentatively referred to this genus. Both sides of the test are evolute, one (the dorsal) completely evolute, the other semi-evolute. There are 12 chambers in the final whorl. Apertural details cannot be ascertained. The specimen could equally well be a discorbid.

Age: Early Miocene, N4.

Genus *CRESPINELLA* Parr, 1942

Crespinella parri Quilty, 1980
(Pl.1, figs 10-12)

Crespinella sp. nov. A: Ludbrook 1961, p.87 *et seq.*, pl.3, figs 7-9.
C. parri Quilty 1980, p.302, figs 4-6.

Type locality and stratigraphic level - Fossil Bluff, Wynyard, Tasmania; Early Miocene.

Occurrence: (a) Great Musselroe Bay - 84483(v); (b) Fossil Bluff - 84011(r), 84012(c), 84013(q), 84025b(v).
Age: Late Oligocene-Early Miocene, N3, N4.

Crespinella umbonifera (Howchin and Parr), 1938
(Pl.1, figs 13,14)

?Operculina umbonifera Howchin and Parr, 1938: *Trans. R. Soc. S. Aust.* 62(2): 309, pl.18, figs 3,4,6,13,14.
Crespinella umbonifera Parr, 1942: *Min. geol. J.* 2(6): 361.
C. umbonifera; Crespin 1943, p.78.
C. umbonifera; Crespin 1944, p.13.
C. umbonifera; Ludbrook 1961: p.87.

Type locality and stratigraphic level - 175-189 m Metropolitan Abattoirs Bore, Adelaide; "Miocene".

A single specimen which has eleven chambers in the final whorl is recorded from Preservation Island. Crespin (1944) recorded it from Cape Barren Island but as I have seen no material from her locality, it is not recorded here. It is mentioned in dealing with the Cape Barren Island deposit.

Occurrence: Preservation Island - 84479(v).

Age: Early Miocene, N8.

Genus *VALVULINERIA* Cushman, 1926
Valvulineria kalimnensis (Parr), 1939
(Pl.1, figs 15-18)

Planulina kalimnensis Parr, 1939: *Min. geol. J.* 1(4): 69, pl.1, figs 19a-c.
P. kalimnensis; Crespin 1943, p.82.
Valvulineria kalimnensis; Carter 1964, p.101, pl.8, figs 157-167.

Type locality and stratigraphic level - Jemmys Point, near Kalimna, Victoria; Pliocene.

The septal structure of this species is identical with that of *Crespinella* (Quilty 1980) and thus it is a true *Valvulineria*. It is an almost ubiquitous and abundant species in the Fossil Bluff section.

Occurrence: (a) Great Musselroe Bay - 84481(r), 84482(r); (b) Fossil Bluff - 84010a(c), 84010b(f), 84011(f), 84012(c), 84014(q), 84015(r), 84016(q), 84017(r), 84021(a), 84022(a), 84023(r), 84025a(q), 84024(q), 84025b(q); (c) Marrawah district - 84561(v).

Age: Early Miocene, N4.

Subfamily CIBICIDINAE
Genus *CIBICIDES* de Montfort, 1808

I have separated the cibicidid species into two genera - *Cibicides* and *Cibicidoides*. For the purpose of the following discussion, they are considered together.

Carter (1964, p.147) presented a diagram of a morphological series involving four species of *Cibicides* - *perforatus*, *mediocris*, *thiara* and *cygnorum* - suggesting (a) branching of *C. mediocris* from *C. perforatus* at about the Faunal Unit 7-Faunal Unit 8 boundary, and (b) a branching of *C. cygnorum* from *C. thiara* at about the Faunal Unit 8-Faunal Unit 9 boundary. The time ranges of the various species involved are not completely known, and all that can be done at the moment in these "genera" is to list groups of closely related species - a very subjective judgement at best.

Text-figure 2 is a range chart of the species of *'Cibicides'* listed by Carter (1958, 1964), Hornibrook (1961) and Reed (1965). Reed's record of *C. pseudoungerianus* is here recorded as *C. perforatus* and *C. verrucosus* is ignored as the available figures and descriptions are insufficient to help place it in a group.

The 22 species recorded in the Australasian region can be broken down into three main groups. They are:

(a) *C. ihungia-lobatulus-notocenicus-pseudoconvexus-thiara-vortex,*
(b) *C. collinsi-opacus-robertsonianus-subhaidingeri,* and
(c) all those that do not fit into one of the above groups.

The first group includes those species with flat dorsal surfaces and often strongly convex ventral surfaces. They all show strong evidence of an attached existence and, in fact, represent true *Cibicides*. The second group contains free living biconvex species with low diameter/thickness ratios and weakly angled margins. *C. victoriensis* may fit

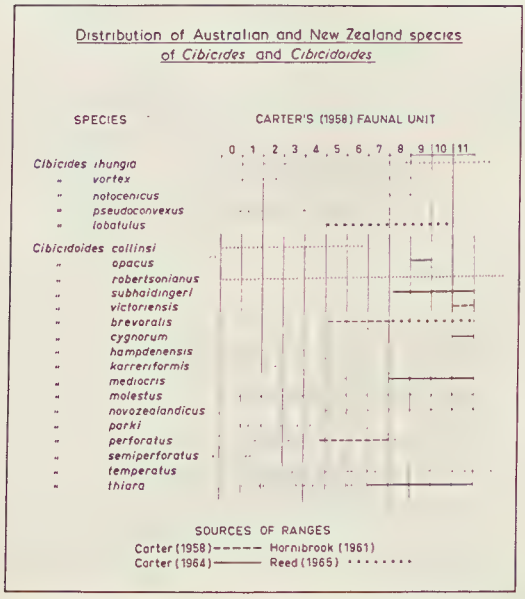

FIG. 2 - The time ranges of various Australian species of *Cibicides* and *Cibicidoides*.

here. The last group - the largest - contains biconvex species with angled margins, higher diameter/thickness ratios. *C. karreriformis* is placed here for convenience although its position is rather doubtful.

In this diagram, no effort is made to construct an evolutionary tree. The diagram only covers that time subdivided by Carter's Faunal Units. This figure suggests that the morphological series depicted by Carter (1964) is not an evolutionary sequence.

Cibicides refulgens de Montfort, 1808
(Pl.1, figs 19,20)

Cibicides refulgens de Montfort, 1808: CONCHYLIOLOGIE SYSTEMATIQUE ET CLASSIFICATION METHODIQUE DES COQUILLES, (F. Schoell: Paris) 1: 123, fig.122.
Truncatulina refulgens (Montfort); Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924), pt.2: 175.
Cibicides refulgens; Crespin 1943, p.78.

Type locality and stratigraphic level - neither designated; localities listed - Tuscany, fossil and Holocene.

Some of the specimens recorded are close to *C. ihungia* Finlay or *C. lobatulus* Walker and Jacob.

Occurrence: (a) King Island - 84084(v), 84081(v), 84475(f), 84476(c), 84477(r); (b) Granville Harbour - 54144(r); (c) Marrawah district - 84114(v).

Age: Early Miocene, N4-N8.

Cibicides thiara (Stache), 1865
(Pl.1, figs 21,22)

Rosalina thiara Stache, 1865: "NOVARA" EXPEDN, GEOL. THEIL, 1(2): 279, pl.24, figs 29-30.
Cibicides thiara (Stache); Carter 1958, p.97, pl.7, figs 136-138.
C. thiara; Hornibrook 1971, p.52, pl.11, figs 188-190.

Type locality and stratigraphic level - Whaingaroa Harbour, New Zealand; Oligocene.

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(c), 84482(c); (b) Fossil Bluff - 84010a(q), 84010b(q), 84012(f), 84013(q), 84014(f), 84015(f), 84016(c), 84017 (q), 84019(q), 84021(f), 84022(f), 84023(a), 84025a(a), 84024(a), 84025b(c); (c) Mt Cameron West - 84121(f), 84120(c); (d) Brittons Swamp - 84480(f); (e) Cape Barren Island - 84554(q); (f) Marrawah district - 84092(r), 84561(c), 84109(q), 84110(q), 84111(q), 84113(q), 84114(q), 84104(q), 84101(q), 84107(f).

Age: Late Oligocene-Early Miocene, N3-N8.

Cibicides vortex Dorreen, 1948
(Pl.1, figs 23-25)

Cibicides vortex Dorreen, 1948: *J. Paleont.* 23: 299, pl.41, fig.5.
C. vortex; Raggatt and Crespin, 1955: *Proc. R. Soc. Vict.* n.s. 67(1): 128.
C. vortex; Hayward and Buzas 1979, p.49, pl.11, figs 138,139.

Type locality and stratigraphic level - Ethel Creek, 8 km southeast of Greymouth, South Island, New Zealand; Late Eocene.

The specimens from King Island are generally poorly preserved and error may exist in some identifications. The most common species being misidentified is probably poorly preserved *C. perforatus*.

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(r), 84482(r); (b) Fossil Bluff - 84011(v), 84013(v); (c) King Island - 84084(c), 84085(f), 84081(q), 84082(c), 84083(c), 84086(c), 84090(p), 84087(q), 84475(r), 84476(r); (d) Daisy Creek - 84478(r); (e) Cape Grim - 84008(q), 84007(q), 84006(q), 84005(a+), 84003(a), 84002(a), 84001(a); (f) Mt Cameron West - 84118(v), 84121(r), 84120(v); (g) Granville Harbour - 54144(f); (h) Brittons Swamp - 84480(v); (i) Cape Barren Island - 84554(r); (j) Redpa - 84093(v), 84094(v), 84095(q), 84096(v); (k) Marrawah district - 84561(q); (l) Welcome River - 45979(c).

Age: Late Oligocene-Early Miocene, N3-N8.

Genus *CIBICIDOIDES* Thalman, 1939
Cibicidoides brevoralis (Carter), 1958
(Pl.1, figs 26,27)

Cibicides molestus Finlay in Battey, 1949: *Trans. R. Soc. N.Z.*, 77: 455. (*Nomen nudum.*)
C. brevoralis Carter 1958, pp. 47,48, pl.6, figs 54-56.
C. molestus; Hornibrook 1961, p. 163, pl.24, figs 478,479,483.
C. brevoralis; Carter 1964, p.95.
C. brevoralis; Reed 1965, p.69.
C. brevoralis; Gibson 1967, p.67, pl.19, figs 275,276.
Cibicidoides brevoralis; Hayward and Buzas 1979, p.49.

Type locality and stratigraphic level - West bank of Barwon River 1 km south of Birregurra, Victoria; Early Miocene.

I have followed the opinion of Gibson (1967) and Hayward and Buzas (1979) in regarding *C. brevoralis* and *C. molestus* as synonyms. Preservation generally is poor.

Occurrence: (a) Fossil Bluff - 84025b(r); (b) Mt Cameron West - 84120(v); (c) Brittons Swamp - 84480(f); (d) Cape Barren Island - 84554(r); (e) Marrawah district - 84109(r), 84111(r), 84113(q), 84114(r).

Age: Early Miocene, N4-N8.

Cibicidoides collinsi (Finlay), 1940

Cibicides collinsi Finlay 1940, p.466.
C. collinsi; Hornibrook 1961, p.161, text figures 5a-c.

Type locality and stratigraphic level - lower part Amuri Limestone, Stoneyhurst, New Zealand; Middle Eocene.

Only a few poorly preserved specimens are referred to this species and it is not figured. It differs from the holotypes figured by Hornibrook (*op. cit.*) in lacking the obvious coarse pores on the dorsal surface. However, in all other respects, it seems almost identical.

Occurrence: (a) Great Musselroe Bay - 84482(v); (b) Fossil Bluff - 84010b(v), 84011(v), 84025b(v); (c) Brittons Swamp - 84480(r); (d) Marrawah district - 84561(q).

Age: Early Miocene, N4-N8.

Cibicidoides perforatus (Karrer), 1864
(Pl.2, figs 1.2)

Rotalia perforata Karrer, 1864: "NOVARA" EXPDN, GEOL. THEIL, 1(2): 81, pl.16, fig.13.
Cibicides perforatus (Karrer); Carter 1958, pp.46,47, pl.6, figs 57-59.
C. perforatus (Karrer); Hornibrook 1961, p.161, pl.25, figs 503-505.
C. perforatus; Carter 1964, p.96.
C. pseudoungerianus (Cushman); Reed 1965, p.79.
Cibicidoides perforatus; Hayward and Buzas 1979, p.49.

Type locality and stratigraphic level - Orakei Bay, New Zealand; Late Oligocene or Early Miocene.

Reed (1965, *op. cit.*) stated that specimens referable to this species are identical with the types of *C. pseudoungerianus* (Cushman). If this is so, the latter is a junior synonym of *C. perforatus* (Karrer). It is probable that many earlier records of *C. ungerianus* (e.g. Howchin 1889, 1891; Chapman, Parr and Collins 1934 etc.) refer to this species.

This is by far the most abundant of the cibicidids in the Tasmanian Tertiary, making up more than 80% of the total fauna in five cases and 40-80% in another ten.

The King Island population of this species has a lower diameter/thickness ratio and can be distinguished from mainland Tasmanian specimens on this basis.

Occurrence: (a) Great Musselroe Bay - 84483(c), 84481(c), 84482(c); (b) Fossil Bluff - 84010a(q), 84010b(a), 84011(c), 84012(f), 84013(c), 84014(c), 84015(a), 84016(a), 84017(a), 84019(a), 84021(c), 84022(q), 84023(f), 84025a(f), 84024(f), 84025b(c); (c) Cape Portland - 84553(r); (d) King Island - 84084(a+), 84085(a+), 84081(a++), 84082(a+), 84083(a+), 84086(a+), 84089(p), 84090(p), 84087(a+), 84475(a+), 84476(a), 84477(a+); (e) Daisy Creek - 84478(a+); (f) Cape Grim - 84008(r), 84007(r), 84006(f), 84005(q), 84003(r), 84002(r), 84001(r);

(g) Mt Cameron West - 84118(a), 84121(a+), 84120(a), 84117(a); (h) Granville Harbour - 54144(a+); (i) Preservation Island - 84479(q); (j) Brittons Swamp - 84480(a); (k) Cape Barren Island - 84554(r); (l) Redpa - 84097(a+), 84093 (a++), 84094(a++), 84095(a++), 84096(a++); (m) Marrawah district - 84092(c), 84561(f), 84109(a+), 84110(a), 84111(a+), 84113(a), 84114(a), 84104(a), 84101 (c), 84105(a), 84106(a), 84107(a); (n) Welcome River - 45979(a).

Age: Late Oligocene-Early Miocene, N3-N8.

Cibicidoides subhaidingeri (Parr), 1950
(Pl.2, figs 3,4)

Cibicides subhaidingeri Parr, 1950: *B.A.N.Z. Antarct. Res. Expedn Rep.* ser.B, vol.5(6): 364, pl.15, figs 79a-c.
C. subhaidingeri; Carter 1964, p.95, pl.9, figs 145-147.
C. subhaidingeri; Reed 1965, p.70.

Type locality and stratigraphic level - B.A.N.Z.A.R.E. Station 115, 148°42'E; 41°03'S: Holocene.

Occurrence: (a) Fossil Bluff - 84010a(v), 84010b(v); (b) Marrawah district - 84104(v).

Age: Early Miocene, N4-N8.

Cibicidoides temperata (Vella), 1957
(Pl.2, figs 5,6)

Cibicides temperata Vella, 1957: *Geol. Surv. N.Z., Pal. Bull.* 28: 40, pl.9, figs 201-203.
C. temperata; Hornibrook 1961: p.162, pl.24, figs 476,477,482.
Cibicidoides temperatus; Hayward and Buzas 1979, p.49, pl.11, figs 135-137.

Type locality and stratigraphic level - off North Cape, New Zealand, in 135 m; Holocene.

Occurrence: (a) Great Musselroe Bay - 84483(q); (b) Fossil Bluff - 84010b(v), 84025a (v); (c) King Island - 84087(v).

Age: Late Oligocene-Early Miocene, N3-N4.

Genus *DYOCIBICIDES* Cushman and Valentine, 1930
Dyocibicides biserialis Cushman and Valentine, 1930
(Pl.2, figs 7,8)

Dyocibicides biserialis Cushman and Valentine, 1930: *Contr. Dept Geol. Stanford Univ.* 1(1): 31, pl.10, figs 1,2.
D. biserialis; Chapman, Parr and Collins 1934, p.572, pl.11, figs 43a-c.
D. biserialis; Carter 1964, p.94, pl.7, figs 130-132.
D. biserialis; Hayward and Buzas 1979, p.52, pl.12, fig.155.

Type locality and stratigraphic level - type locality not given. Leeward side of San Clemente, Santa Catalina, Santa Cruz and Anacapa Islands, California; Holocene.

Following Nyholm (1961) this species should be placed, biologically speaking, within *Cibicides*, *Dyocibicides* being a junior synonym of that genus. Reed (1965) would also place *Vagocibicides* (now *Karreria*) here, but several authors (Carter 1964; Loeblich and Tappan 1964, etc.) have given ample reasons for regarding *Vagocibicides* as a genus quite distinct from *Cibicides*.

Whether this species is a separate one, or derived from normal *Cibicides* is not clear It could be an irregular attached form of *C. thiara* or of several other species. It is here taken as a distinct species.

As well as typical specimens, many irregular variants of *Cibicides* are included here.

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(r); (b) Fossil Bluff - 84010b(v), 84014(r), 84015(r); (c) Cape Grim - 84008(q), 84007(r), 84006(q); (d) Mt Cameron West - 84118(v); (e) Granville Harbour - 54144(r); (f) Redpa - 84097(q), 84093(q), 84096(v); (g) Marrawah district - 84110(v), 84113(r), 84114(r), 84104(q), 84105(r), 84106(q), 84107(r).

Age: Late Oligocene-Early Miocene, N3-N8.

Family PLANORBULINIDAE
Genus *PLANORBULINA* d'Orbigny, 1826
Planorbulina mediterranensis d'Orbigny, 1826
(Pl.2, fig.9)

Planorbulina mediterranensis d'Orbigny, 1826: *Annls Sci. Nat.* ser.1, 7: 280, pl.14, figs 4-6.
P. mediterranensis; Howchin 1889, p.13.
P. mediterranensis; Howchin 1891, p.352.
P. mediterranensis; Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924): 173.
P. mediterranensis; Howchin and Parr, 1938: *Trans. R. Soc. S. Aust.* 62: 311, pl.19, fig.12.
P. mediterranensis; Crespin 1943, p.82.

Type locality and stratigraphic level - Mediterranean coast; Holocene.

Occurrence: (a) Great Musselroe Bay - 84481(v); (b) Cape Grim - 84001(v); (c) Cape Portland - 84553(r); (d) Mt Cameron West - 84120(v).

Age: Early Miocene, N4.

Genus *PLANORBULINELLA* Cushman, 1927
Planorbulinella inaequilateralis (Heron-Allen and Earland), 1924
(Pl.2, figs 10-12)

Planorbulina larvata var. *inaequilateralis* Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924): 174, pl.12, figs 85-90.
Planorbulinella inaequilateralis; Crespin 1936: *Palaeont. Bull., Canberra* 2: pl.1, fig.6.
P. inaequilateralis; Crespin 1943, p.82.
P. inaequilateralis; Carter 1958, p.58.
P. inaequilateralis; Carter 1964, p.126, pl.13, figs 269-271.

Type locality and stratigraphic level - "Dryden" or "Filter Quarry", Moorabool River, Victoria; "Miocene".

From Fossil Bluff (84010a) a few specimens of *Planorbulinella* were recovered. One of these was sectioned. The specimen is not easy to place specifically, probably being intermediate between *P. johannae* Carter and *P. inaequilateralis*. Externally it is indistinguishable from *P. inaequilateralis* and internally is closer to it than to *P. johannae*. A protoconch of 0.07 mm is followed by a deuteroconch of 0.09 mm. At each side of the junction of this pair is a primary auxiliary chamber. Each of these gives rise to two spirals of interauxiliary chambers. The spiral alongside the protoconch has only one interauxiliary chamber in each case and both terminate at a symmetrical interauxiliary chamber. Each spiral alongside the deuteroconch has two interauxiliary chambers. The specimen thus differs from *P. inaequilateralis* in having only one interauxiliary chamber in each spiral alongside the protoconch. This amount of variation could perhaps be expected within the species.

If this species does fit within the variation of *P. inaequilateralis* this is probably the earliest record of it. Carter (1958, 1964) used it as an index species for the advent of Faunal Unit 7.

Occurrence: (a) Fossil Bluff - 84010a(v); (b) Preservation Island - 84479(r); (c) Cape Barren Island - 84554(r); (d) Marrawah district - 84104(v).

Age: Early Miocene, N4-N8.

Planorbulinella plana (Heron-Allen and Earland), 1924
(Pl.2, figs 13,14)

Planorbulina plana Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924): 174, pl.12, figs 92-95.
Planorbulinella plana (Heron-Allen and Earland); Crespin 1936: *Palaeont. Bull., Canberra* 2: 4,5,6.
P. plana; Howchin and Parr, 1938: *Trans. R. Soc. S. Aust.* 62: 306.
P. plana; Crespin 1943, p.82.
P. plana; Carter 1958, p.58, pl.8, figs 79-80.
P. plana; Carter 1964, p.126.
P. plana; Cooper 1979: *Rept Invest. Geol. Surv. S. Aust.* 50: pl.19, fig.7.

Type locality and stratigraphic level - "Dryden" or "Filter Quarry", Moorabool River, Victoria; "Miocene".

Only a single specimen was recovered from each of the samples listed. One specimen was sectioned. It is a microspheric specimen beginning with an initial coiled portion.

Occurrence: (a) Cape Barren Island - 84554(r); (b) Marrawah district - 84114(v), 84104(v).

Age: Early Miocene, N8.

Family ACERVULINIDAE
Genus *GYPSINA* Carter, 1877
Gypsina globulus (Reuss), 1848
(Pl.2, fig.15)

Ceriopora globulus Reuss, 1848: *Naturw. Abh. Berl.* 2(1): 33.
Gypsina globulus (Reuss); Howchin 1889, p.14.
G. globulus; Chapman, 1910: *Proc. R. Soc. Vict.* n.s., 22: 290.
G. globulus; Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924): 183, pl.14, figs 117-118.
G. globulus; Crespin 1943, p.80.

Type locality and stratigraphic level - Nüssdorf, Vienna, Austria; Tertiary.

The specimens from the Great Musselroe Bay and Fossil Bluff samples are much smaller than is usual for the species and are not only globular, but often have a flattened area on one side of the "sphere". They have been compared with Holocene specimens from Timor.

A few abraded specimens from Marrawah (84114) are placed here. They lack the distinctive embryonic chamber arrangement and regular adult chamber arrangement of *G. howchini*. The specimens are not spherical but discoidal to inflated discoidal.

Occurrence: (a) Great Musselroe Bay - 84481(r), 84482(r); (b) Fossil Bluff - 84010a(v); (c) Cape Barren Island - 84554(q); (d) Marrawah district - 84114(r).

Age: Early Miocene, N4-N8.

Gypsina howchini Chapman, 1910
(Pl.2, fig.16)

Gypsina howchini Chapman, 1910: *Proc. R. Soc. Vict.* n.s. 22: 291, pl.2, figs 4a,b; pl.3, figs 3-5.
G. howchini; Heron-Allen and Earland, 1924: *J. R. microsc. Soc.* (1924): 183.
G. howchini; Crespin, 1936: *Palaeont. Bull., Canberra* 2: pl.1, figs 7,8.
G. howchini; Howchin and Parr, 1938: *Trans. R. Soc. S. Aust.* 62: 312.
G. howchini; Crespin 1943, p.80.
G. howchini; Carter 1958, p.23.
G. howchini; Ludbrook 1961, pp.87 *et seq.*, pl.4, fig.3.
G. howchini; Carter 1964, p.82, pl.4, figs 82-85; pl.15, fig.283.

Type locality and stratigraphic level - Batesford Limestone (1) Upper Quarry Batesford and (2) Filter Quarry, Moorabool River, Victoria; Early Miocene.

Occurrence: Cape Barren Island - 84554(v).

Age: Early Miocene, N8.

Gypsina sp.
(Pl.2, fig.17)

A few specimens of a large encrusting species were recovered from Cape Grim and the Marrawah district. The general growth pattern resembles that of *G. mastelensis* Bursch, or *G. vesicularis* (Parker and Jones) var. *squamiformis* Chapman. Maximum diameter is about 2 mm and the test is composed of a layer of irregularly formed chambers.

Occurrence: (a) Cape Grim - 84007(r), 84006(v); (b) Marrawah district - 84092(v), 84108(r).

Age: Early Miocene, N4-N8.

Family HOMOTREMATIDAE
Subfamily VICTORIELLINAE
Genus *CARPENTERIA* Gray, 1858
Carpenteria balaniformis Gray, 1858
(Pl.2, figs 18,19)

Carpenteria balaniformis Gray, 1858: *Proc. Zool. Soc.* (1858): 296, figs 1-4 (p.268).
C. balaniformis; Loeblich and Tappan 1964, C707, fig.580, 1-4.

Type locality and stratigraphic level - Philippine Islands; Holocene.

Occurrence: (a) Great Musselroe Bay - 84483(v); (b) Fossil Bluff - 84010a(v).

Age: Late Oligocene-Early Miocene, N3, N4.

Carpenteria rotaliformis Chapman and Crespin, 1930
(Pl.2, fig.20)

Carpenteria rotaliformis Chapman and Crespin, 1930: *Proc. R. Soc. Vict.* n.s., 43: 98,99, pl.5, figs.7,8.
C. rotaliformis; Chapman, Parr and Collins 1934, pp.572,573, pl.11, fig.44.
C. rotaliformis; Howchin and Parr 1938: *Trans. R. Soc. S. Aust.* 62: 312, pl.19, figs 3,4.
C. rotaliformis; Crespin 1943, p.77.
C. rotaliformis; Glaessner and Wade 1959: *Micropaleontology* 5: 200, pl.2, fig.6.
C. rotaliformis; Carter 1964, p.81.
C. rotaliformis; Reed 1965, p.80, pl.12, figs 4,7,8,11.

Type locality and stratigraphic level - No.1 Bore, Parish of Bumberrah (Metung), Victoria; "Tertiary".

Occurrence: (a) Great Musselroe Bay - 84483(q), 84481(r), 84482(r); (b) Mt Cameron West West - 84118(r), 84120(r), 84117(f); (c) Granville Harbour - 54144(r); (d) Preservation Island - 84479(v); (e) Cape Barren Island - 84554(v); (f) Marrawah district - 84110(v), 84113(r), 84114(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Superfamily ROTALIACEA
Family ROTALIIDAE
Genus *AMMONIA* Brunnich, 1772
Ammonia cf. *beccarii* (Linné), 1767

Nautilus beccarii Linné, 1767: SYSTEMA NATURAE, 12th edn: 1162.
Ammonia beccarii; Margerel, 1968: FORAM. REDONIEN,: 133, pl.24, figs 29-31; pl.25, figs 1.3.

Type locality and stratigraphic level - Adriatic and Mediterranean Seas; Holocene.

From Cape Portland, northeastern Tasmania, come a few fragmentary specimens which may belong here and which, by virtue of their position, may be part of the Tertiary sequence.

Occurrence: Cape Portland - 84553(v).

Subfamily CHAPMANININAE
Genus *SHERBORNINA* Chapman, 1922
Sherbornina atkinsoni Chapman, 1922
(Pl.2, figs 21-26)

Sherbornina atkinsoni Chapman, 1922: *J. Linn. Soc.* 34(230): 501-503, pl.32, figs 1-5.
S. atkinsoni; Crespin 1943, p.83.
S. atkinsoni; Wade and Carter 1957: *Micropaleontology* 3(2): 157,158, pl.1, figs 1-5; pl.2, figs 1-3; pl.3, figs 1-3.
S. atkinsoni; Carter 1958, pp.17 *et seq.*
S. atkinsoni; Ludbrook 1961, pp.87 *et seq.*
S. atkinsoni; Hayward 1978, p.231, pl.1, figs 9-12; pl.2, figs 24-26; pl.3; pl.4, figs 40, 41.
S. atkinsoni; Cooper 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.10.

Type locality and stratigraphic level - Fossil Bluff, Wynyard, Tasmania; Early Miocene.

Sherbornina cuneimarginata is superficially distinct from *S. atkinsoni* in being concavo-convex rather than simple discoidal. A single well preserved specimen from Mt Cameron West (84118) was placed in *S. cuneimarginata* before sectioning, on the basis of its superficial characters. It was almost identical with Wade and Carter's figures 6a-c (pl.1). When sectioned however, it is more like *S. atkinsoni* and is recorded as that species. It is probably a young specimen of *S. atkinsoni*, about Faunal Unit 7 in age.

The Brittons Swamp occurrence is in a different specimen from other Brittons Swamp species recorded herein. The rock is well indurated. The particular boulder is probably older than the other one studied.

Occurrence: In none of the Tasmanian occurrences is *Sherbornina* associated with warm-water large foraminiferids as Hayward (1978) suggested it should be. However, it is never common.
(a) Great Musselroe Bay - 84483(v); (b) Fossil Bluff topotypes - 84010a(v); (c) King Island - 84477(r); (d) Daisy Creek - 84478(r); (e) Mt Cameron West -

84118(v); (f) Brittons Swamp; (g) Marrawah district - 84561(v).

Age: Late Oligocene-Early Miocene, N3-N4.

Genus *TENISONINA* Quilty, 1980
Tenisonina tasmaniae Quilty, 1980
(Pl.3, figs 1-6)

Tenisonina tasmaniae Quilty 1980, p.305, figs 7,8.

Type locality and stratigraphic level - Cape Grim, Tasmania; Early Miocene.

Hayward (1978) figured as *Sherbornina atkinsoni* variant B, specimens from the Oligocene of France, which have most of the features of this genus. Hayward suggested that this may be "a schizogonous resting stage in the life cycle of *S. atkinsoni*, similar to the planorbulinoid forms of *Cibicides lobatulus*."

I have taken *Tenisonina* as a distinct genus because at Cape Grim and at Welcome River, it occurs abundantly in many samples, without any specimens which could be referred to *Sherbornina s.s.* Also, taking this as *Sherbornina* would invalidate the generalisation (Hayward, p.236) that the association is invariably with large shallow warm water foraminiferids when common.

Occurrence: In Tasmania this species is known only from Cape Grim and Welcome River. (a) Cape Grim - 84008(v), 84007(f), 84006(f), 84005(f), 84003(a), 84002(f), 84001(f); (b) Welcome River - 45979(f).

Age: Early Miocene, N4.

Family CALCARINIDAE
Genus *CALCARINA* d'Orbigny, 1826

Two species, *C. mackayi* (Karrer) and *C. verriculata* (Howchin and Parr), are recognised and both are placed in *Calcarina* although some recent works (e.g. Hornibrook 1971) have placed *C. mackayi* in *Pararotalia*.

The form identified here as *C. verriculata* has the characteristics of *Calcarina*, including solid peripheral spines, clearly visible on pl.3, fig.10, which shows how these spines are overgrown by later whorls. On a purely morphological basis, that form identified here as *C. mackayi* could be placed in *Pararotalia*, lacking peripheral spines and having characteristics of that genus. Samples from Fossil Bluff and Great Musselroe Bay contain both forms and they seem to intergrade suggesting that they should at least be placed in the same genus (and thus also the same family). Historically, it is interesting to note that Chapman, Parr and Collins (1934) equated *C. mackayi* with *C. spengleri*, taken by Loeblich and Tappan (1964) as the type species for *Calcarina*.

Calcarina mackayi (Karrer), 1865
(Pl.3, figs 7,8)

Rosalina mackayi Karrer, 1865: "NOVARA" EXPDN GEOL. THEIL 1: 82, pl.16, figs 14a-d.
Rotalia calcar; Heron-Allen and Earland 1924: *J. R. microsc. Soc.* (1924): 181.
Calcarina cf. *spengleri*; Chapman, Parr and Collins 1934, p.568, pl.9, figs 15a-c.
C. mackayi; Carter 1958, p.68, pl.2, figs 10-12.
Pararotalia mackayi; Hornibrook, 1971, p.19, pl.3, figs 55-57; pl.13, figs 3-7.

Type locality and stratigraphic level - Orakei Bay Greensand, Hobson Bay, Waitemata Harbour, New Zealand; Early Miocene.

Unabraded specimens of both *C. mackayi* and *C. verriculata* (Howchin and Parr) are found in the same samples from Great Musselroe Bay and Fossil Bluff. They are often hard to distinguish, but can be separated on several bases. *C. mackayi* has a more or less conical ventral surface and clearly angled margin. *C. verriculata* has roughly parallel ventral and dorsal surfaces and rounded margins. The latter species generally is more pustulose on the dorsal surface. However, it may occasionally be more or less plane. It also appears to be larger than *C. mackayi*. *C. mackayi* generally has a less "ornamented" ventral surface. *C. verriculata* has the well-developed large peripheral spines characteristic of *Calcarina*. The origin of the coarse pores visible on both surfaces is unknown.

In the samples from Preservation Island, both species are recorded but this may be a result of the apparent fact that *C. mackayi*, when somewhat abraded, looks rather like *C. verriculata*.

Occurrence: (a) Great Musselroe Bay - 84483(v), 84481(q); (b) Fossil Bluff - 84010a(v), 84012(v), 84025a(r); (c) Cape Portland - 84553(v); (d) Mt Cameron West - 84118(q), 84121(v), 84117(r); (e) Preservation Island - 84479(c); (f) Cape Barren Island - 84554(a+); (g) Marrawah district - 84092(q), 84561(v); (h) Welcome River - 45979(c).

Age: Late Oligocene-Early Miocene, N3/4, N8.

Calcarina verriculata (Howchin and Parr), 1938
(Pl.3, figs 9,10)

Rotalia calcar; Chapman 1910: *Proc. R. Soc. Vict.* 22(2): 289, pl.53, fig.2.
Calcarina defrancii, Heron-Allen and Earland 1924: *J. R. microsc. Soc.* (1924), pt.2: 182.
Rotalia verriculata Howchin and Parr 1938: *Trans. R. Soc. S. Aust.* 62(2): 310, pl.19, figs 8,9,11,15.
Calcarina verriculata; Crespin 1943, p.77.
C. verriculata; Ludbrook 1961, pp.50,87 etc., pl.4, figs 6,7.
Pararotalia verriculata; Cooper 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.4.

Type locality and stratigraphic level - 216-259 m Metropolitan Abattoirs Bore, Adelaide; "Lower Miocene".

Occurrence: (a) Great Musselroe Bay - 84483(v); (b) Fossil Bluff - 84010a(r); (c) Preservation Island - 84479(c); (d) Marrawah district - 84114(v), 84104(q), 84101(a).

Age: Late Oligocene-Early Miocene, N3-N8.

Family ELPHIDIIDAE
Subfamily ELPHIDIINAE
Genus *CRIBROELPHIDIUM* Cushman and Bronnimann, 1948
Cribroelphidium poeyanum (d'Orbigny), 1839
(Pl.3, fig.11)

Polystomella poeyana, d'Orbigny (in de la Sagra, 1839): HISTOIRE PHYSIQUE, POLITIQUE, ET NATURELLE DE L'ÎLE DE CUBA, (A. Bertrand: Paris): 55, pl.6, figs 25-26.

Type locality and stratigraphic level - Cuba and Jamaica; Holocene.

There seems to be no previous record of this species from Tertiary rocks in Australia. The specimens found here agree in most details with the descriptions and figures of *C. poeyanum* in Cushman (1939, p.54, pl.14, figs 25,26) and Loeblich and Tappan (1964, p.C635, fig.508,3,4), except that the present species is less compressed, the figured specimen having a diameter/thickness ratio of 2:1 instead of 5:2. The difference does seem to be a consistent one.

Occurrence: (a) Great Musselroe Bay - 84481(v); (b) Fossil Bluff - 84022(r), 84025a(q), 84024(r), 84025b(v); (c) Cape Portland - 84553(a+).

Age: Early Miocene, N4.

Genus *ELPHIDIUM* de Montfort, 1808

Elphidium chapmani Cushman, 1936

(Pl.3, fig.12)

Elphidium chapmani Cushman 1936: *Contr. Cushman Lab. foramin. Res.* 12: 80, pl.14, fig.6.
E. parri Cushman 1936, *ibid.*: 81, pl.14, fig.7.
E. chapmani; Howchin and Parr 1938: *Trans. R. Soc. S. Aust.* 62(2): 308.
E. chapmani; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 47, pl.12, fig.17.
E. parri; Cushman 1939, *ibid.*: 47,48, pl.12, fig.18.
E. chapmani; Crespin 1943. p.79.
E. parri; Crespin 1943, p.79.
E. chapmani; Carter 1964, p.120, pl.12, figs 245,246.
E. parri; Reed 1965, p.70.

Type locality and stratigraphic level - Neumerella, Victoria; "Miocene".

Elphidium chapmani and *E. parri* are here regarded as synonymous. Cushman noted several differences between the two "species" when he erected them. They are -
(a) *E. chapmani* has a rhomboid cross section whereas *E. parri* has flattened, parallel sides.
(b) *E. chapmani* has 25-30 chambers in the final whorl while *E. parri* has only 20-25.
(c) *E. chapmani* has 20 or more retral processes on each chamber whereas *E. parri* has only 7-8.
(d) *E. chapmani* has a diameter of 1.25 mm while *E. parri* has one of 0.70-0.80 mm.

In most other respects he regarded the species as very similar. The types of both species probably come from the same sample from Neumerella, Victoria. The first three differences cited are fairly clearly the result of the fourth. As test size increases, the number of chambers per whorl increases, the number of retral processes per chamber increases, and probably the outline changes. There seems to be a complete intergradation. This is also evident in previously published figures of the species. Carter (1964) illustrated a specimen of *E. chapmani* with only 21 chambers in the final whorl — an *E. parri* character — but a rhomboid section — an *E. chapmani* character. He gave the size of the specimen as 0.95 mm — another intermediate property. Carter may have considered them synonyms, as he stated that *E. chapmani* has 20-30 chambers in the final whorl.

Occurrence: (a) Great Musselroe Bay - 84481(v); (b) Fossil Bluff - 84010a(r), 84010b(v), 84011(q), 84012(q), 84013(r), 84022(r), 84025a(v), 84024(r), 84025b(r); (c) King Island - 84476(r); (d) Preservation Island - 84479(v); (e) Brittons Swamp - 84480(v).

Age: Early Miocene, N4-N8.

Elphidium crassatum Cushman, 1936

(Pl.3, fig.13)

Elphidium crassatum Cushman 1936: *Contr. Cushman Lab foramin. Res.* 12: 81, pl.14, figs 8a,b.
E. crassatum; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 41, pl.11, figs 3a,b.
E. crassatum; Crespin 1943, p.79.
E. crassatum; Carter 1964, p.120, pl.12, figs 242-244.

Type locality and stratigraphic level - Muddy Creek, Victoria, brown marl lower beds; "Oligocene" (strictly perhaps Early to Middle Miocene transition).

Occurrence: Marrawah - 84527.

Age: Early Miocene, N8.

Elphidium crespinae Cushman, 1936
(Pl.3, fig.14)

Elphidium crespinae Cushman 1936: *Contr. Cushman Lab. foramin. Res.* 12: 78, pl.14, figs 1a,b.
E. crespinae; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 41, pl.11, fig.1.
E. crespinae; Crespin 1943, p.79.
E. crespinae; Carter 1964, p.121, pl.12, figs 240,241.
E. crespinae; Reed 1965, p.70.

Type locality and stratigraphic level - Muddy Creek, Victoria, brown marl lower beds; "Oligocene" (strictly perhaps Early to Middle Miocene transition).

There seems to exist a similar confusion concerning this species to that concerning *E. chapmani* and *E. parri*. Small specimens are lenticular and after a certain ontogenetic stage has been reached, there is no appreciable increase in thickness, giving rise to flat, parallel sided, specimens.

Cushman (1939, p.41) stated that an adult specimen has 16-18 chambers per whorl, 12-15 retral processes per chamber and no keel. However, his figure (pl.11, fig.1) seems to show a keel. Carter (1964, p.121) said that it has up to 15 chambers per whorl and 10-12 retral processes. The two descriptions are mutually exclusive.

The specimens included here have 12-17 chambers per whorl. The smaller specimens are lenticular with 12-15 chambers per whorl and only five or so retral processes. This sample seems to be intermediate between Cushman's and Carter's concept and it seems probable that this species is more variable than either Cushman or Carter realised. It may also be that *E. crespinae* and possibly *E. howchini* are conspecific. Specimens of both species occur in the lower beds at Muddy Creek, Victoria.

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(q), 84482(q); (b) Fossil Bluff - 84010a(q), 84010b(v), 84012(r), 84013(f), 84022(r), 84025a(q), 84024(q), 84025b(r); (c) King Island - 84085(q); (d) Preservation Island - 84479(r); (e) Mt Cameron West - 84118(r), 84121(v), 84120(r); (f) Marrawah district - 84092(f), 84561(f), 84109(r), 84110(r), 84111(r), 84113(r), 84114(v), 84104(r), 84105(v), 84107(r).

Age: Late Oligocene-Early Miocene, N3-N8.

Elphidium grimensis Quilty, 1980
(Pl.3, figs 15,16)

Elphidium grimensis Quilty 1980, p.308, figs 10,11.

Type locality and stratigraphic level - Cape Grim, Tasmania; Early Miocene.

Occurrence: (a) King Island - 84082(r), 84083(r); (b) Cape Grim - 84008(v), 84007(q), 84003(q), 84002(q), 84001(q); (c) Preservation Island - 84479(r); (d) Marrawah district - 84561(v).

Age: Early Miocene, N4-N8.

Elphidium helenae Quilty, 1980
(Pl.3, figs 17,18)

Elphidium helenae Quilty 1980, p.309, figs 12,13.

Occurrence: (a) Fossil Bluff - 84010a(q), 84010b(q), 84013(c), 84014(q), 84015(r), 84016(f), 84017(f), 84019(f), 84021(f), 84022(c), 84023(f), 84025a(c),

84024(f), 84025b(c); (b) Cape Portland - 84553(r); (c) Mt Cameron West - 84121(v), 84120(v); (d) Marrawah district - 84092(r).

Age: Early Miocene, N4.

Elphidium musselroeensis Quilty, 1980
(Pl.3, figs 19-21)

Elphidium musselroeensis Quilty 1980, p.310, fig.14.

Type locality and stratigraphic level - Great Musselroe Bay, Tasmania; Late Oligocene or Early Miocene.

Occurrence: Great Musselroe Bay - 84483(v).

Age: Late Oligocene, N3.

Elphidium pseudoinflatum Cushman, 1936
(Pl.3, figs 22,23)

Elphidium pseudoinflatum Cushman 1936: *Contr. Cushman Lab. foramin. Res.* 12: 80, pl.14, figs 5a,b.
E. subinflatum Cushman 1936: *ibid.*: 84, pl.15, figs 1a,b.
E. pseudoinflatum; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 41,42, pl.11, fig.8.
E. subinflatum; Cushman 1939: *ibid.*: 48, pl.12, figs 20a,b.
E. pseudoinflatum; Crespin 1943, p.79.
E. pseudoinflatum; Carter 1964, pp.122,123, pl.13, figs 254,255.
E. pseudoinflatum; Hayward and Buzas 1979, p.53, pl.13, figs 166-168.

Type locality and stratigraphic level - *Lepidocyclina* Limestone, Batesford, Victoria; Early Miocene.

Carter (1964) may have been correct in regarding *E. subinflatum* and *E. pseudoinflatum* as synonymous. Specimens referable to both species are found here but the preservation of the *E. pseudoinflatum* morphotype specimens is so poor that no conclusions can be made from a study of the Tasmanian material. The Great Musselroe Bay specimens are closer to the *E. subinflatum* morphotype.

Many specimens seem to have more than the typical seven to nine chambers most of the older specimens having about nine to ten chambers in the final whorl.

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(r), 84482(r); (b) Brittons Swamp - 84480(v); (c) Marrawah district - 84114(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Elphidium sp. 1
(Pl.3, figs 24-25)

In several Cape Grim samples, there is a small species with a bluntly angled (non-carinate) margin. It is very similar to Cushman's (1939) figure (pl.12, fig.1) of *E. orterburgense* (Egger) except that the species I record here is noncarinate. It may be either (a) *E. orterburgense*, (b) a new species or (c) a juvenile variant of *E. grimensis* Quilty from which it seems to differ in being less regular, smaller and less carinate.

Occurrence: Cape Grim - 84008(v), 84002(v), 84001(v).

Age: Early Miocene, N4, N8.

Elphidium sp. 2
(Pl.3, figs 26,27)

Many specimens were recovered from the Cape Grim section of a species of the *E. pseudoinflatum-subinflatum* type, i.e. with flaring sides to the last few chambers. They are distinct from either of those morphotypes in having 12-14 chambers in the final whorl. They seem to be distinct from any previously described species but the preservation is not very good so they are only listed informally. Two very poorly preserved specimens from Cape Barren Island are also tentatively placed here.

Occurrence: (a) Cape Grim - 84008(r), 84007(q), 84006(v), 84005(v), 84002(v), 84001(r);
(b) Cape Barren Island - 84554(r).

Age: Early Miocene, N4, N8.

Subfamily FAUJASININAE
Genus *NOTOROTALIA* Finlay, 1939

I include in *Polystomellina*, *P. australis* Cushman, *P. discorbinoides* Yabe and Hanzawa, and *P. miocenica* Cushman. *Notorotalia zelandica* Finlay is excluded and thus stands as the type of *Notorotalia* and the generic name *Porosorotalia* Voloshinova is a junior synonym. *N. zelandica* is excluded because of its strongly reticulated surface pattern which is characteristic of *Notorotalia* but not of *Polystomellina*.

Polystomellina is characterised by being quite compressed, and in having the properties of *Elphidium* except in being trochospiral. It has probably been derived from a compressed species of *Elphidium*. The species assigned to *Notorotalia*, *Cribrorotalia* and *Porosorotalia* are probably derived from a different stock altogether. They are not so compressed, have much less well developed retral processes and seem to be much more distinct from *Elphidium*. They characteristically also have a more strongly reticulated surface pattern.

Most of the species placed in *Porosorotalia* are here considered to belong to *Notorotalia*. The diagnosis of the genus given by Loeblich and Tappan (1964) must be amended to allow the number of chambers in the final whorl to vary within wider limits than those set at 10-13.

Notorotalia howchini (Chapman, Parr and Collins), 1934
(Pl.4, figs 1-3)

Rotalia howchini Chapman, Parr and Collins 1934, p.566, pl.9, figs 20a-c.
Notorotalia crassimura Carter 1958, p.64, pl.10, figs 101-103.
N. howchini; Carter 1958, *ibid.*: p.65, pl.10, figs 104-106.
N. crassimura; Ludbrook 1961, pp. 87 *et seq.*, pl.2, figs 4,5.
N. howchini; Cooper 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.9.

Type locality and stratigraphic level - Altona Bay Coal Shaft, Port Phillip area, Victoria; Middle Miocene.

It is impossible to separate Carter's species *N. crassimura* from *N. howchini* using Carter's description. The species is very common in the Tasmanian Tertiary but only one species seems to be identifiable.

Carter stated that *N. crassimura* has 17-20 chambers in the final whorl. He figured a specimen with 14. Ludbrook (1961) figured a specimen with about 13. Specimens referable to *N. crassimura* here have 9-15 chambers in the final whorl. Carter stated that *N. howchini* has 8-11 chambers in its ultimate whorl, whereas the original description lists the figure as 10-12. Another distinguishing character Carter lists is in the umbonal boss. His species has a large umbonal boss and *N. howchini* should have none. The original

description of the latter species lists a beaded umbilical region. This only seems to occur if there is an umbilical boss. The beaded umbilical region is common in *N. crassimura*. In any population, specimens range between those with an umbonal boss and those without one. The dorsal "ornamentation" varies from simple beaded sutures (similar to Carter's figures of *N. crassimura*) to anastomosing vermiform markings.

There may be more than one species of *Notorotalia* in this part of the Australian Tertiary, and *N. crassimura* may be distinguishable from *N. howchini*, but the problem needs more study. The "species" do not appear to be distinct.

Many of the specimens may be referable to some of the morphotypes of this genus recognised by New Zealand palaeontologists.

Occurrence: (a) Great Musselroe Bay - 84483(q), 84481(f), 84482(f); (b) Fossil Bluff - 84010a(q), 84010b(f), 84011(r), 84012(v), 84013(q), 84014(q), 84015(q), 84017(f), 84019(f), 84025a(r), 84024(q), 84025b(r); (c) King Island - 84475 (r), 84476(r), 84477(q); (d) Cape Grim - 84008(f), 84007(c), 84006(f), 84005(c), 84003(c), 84002(q), 84001(f); (e) Granville Harbour - 54144(r); (f) Preservation Island - 84479(q); (g) Brittons Swamp - 84480(c); (h) Redpa - 84094(v); (i) Marrawah district - 84561(c); (j) Welcome River - 45979(c).

Age: Late Oligocene-Early Miocene, N3-N8.

Notorotalia spp. indet.

Preservation in chalky rocks makes species of this genus particularly hard to identify. Any recrystallisation makes the task virtually impossible, rendering much of the delicate "ornamentation" indecipherable. In most of the King Island and Marrawah samples, members of this genus are thus rendered unidentifiable. In a few samples the species appear close to *Cribrorotalia dorreeni* Hornibrook. In most samples the specimens are unidentifiable even tentatively.

Specimens (one well preserved, UTGD 84434) of an apparently undescribed species were extracted from the Granville Harbour material.

Occurrence: I *Cribrorotalia* cf. *dorreeni* - (a) King Island - 84084(r), 84085(q), 84083(q), 84090(p); (b) Marrawah district - 84110(q);
II *Nororotalia* spp. indet. - (a) Great Musselroe Bay - 84481(v); (b) King Island - 84084(c), 84085(r), 84083(v); (c) Mt Cameron West - 84118(v), 84121(q), 84120(f), 84117(c); (d) Cape Barren Island - 84554(q); (e) Marrawah district - 84092(c), 84113(q), 84114(q), 84104(r), 84101(q), 84105 (f), 84106(f), 84107(c).
III *Notorotalia?* n. sp. - Granville Harbour - 54144(q).

Age: Early Miocene, N4-N8.

Genus *POLYSTOMELLINA* Yabe and Hanzawa, 1923
Polystomellina miocenica Cushman, 1936
(Pl.4, figs 4,5)

Polystomellina miocenica Cushman 1936: *Contr. Cushman Lab. foramin. Res.* 12: 87, pl.15, figs 8a-c.
P. miocenica; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 69, pl.19, fig.13.
P. miocenica; Crespin 1943, p.82.
Notorotalia miocenica; Carter 1964, p.125, pl.13, figs 260-262.
N. miocenica; Hayward and Buzas 1979, p.67, pl.22, figs 274-278.

Type locality and stratigraphic level - Filter Quarries, Batesford, Victoria; "Miocene".

Although Carter (1964) placed this species in *Notorotalia* it is placed more properly in *Polystomellina* because of the compressed test and low ventral surface. This species normally has of the order of 16 or more chambers in an adult whorl. The specimen figured here has only 14 but it is chosen because it is about the best preserved specimen recovered. The curvature of the sutures is very atypical of *Porosorotalia* and the "ornament" of the ventral surface is much more like that of *Polystomellina*. Although Carter's diagnosis of the species stated that the species has more than 20 chambers in the final whorl, this is not so. It may be so in a few specimens, but most have less than 20, and more than 16. His figured specimen has 17, and Cushman's (1939) figured specimen has 18.

Occurrence: Marrawah district - 84104(q), 84101(q).

Age: Early Miocene, N8.

Family NUMMULITIDAE
Genus *OPERCULINA* d'Orbigny, 1826
Operculina victoriensis Chapman and Parr, 1938
(Pl.4, figs 6,7)

Operculina complanata; Chapman 1910: *Proc. R. Soc. Vict.* n.s. 22: 294.
O. complanata Defrance var. *granulosa*; Chapman 1910: *ibid.*: 294.
O. victoriensis Chapman and Parr 1938: *Proc. R. Soc. Vict.* n.s. 50: 284, pl.16, figs 3-8.
O. victoriensis; Howchin and Parr 1938: *Trans. R. Soc. S. Aust.* 62: 305, pl.18, fig.10.
O. bartschi; Crespin 1936: *Palaeont. Bull., Canberra* 2: 4, pl.1, fig.12.
O. victoriensis; Crespin 1943, p.82.
O. victoriensis; Carter 1958, p.23.
O. victoriensis; Ludbrook 1961, pp.87 *et seq.*, pl.5, fig.3.
O. victoriensis; Carter 1964, p.128, pl.13, figs 266,267.
Camerina complanata; Reed 1965: p.80, pl.12, figs 2,5,9,10,12.

Type locality and stratigraphic level - Red Bluff, Shelford, Victoria; "Lower Miocene".

O. victoriensis is taken as being different from *O. complanata* mainly in having a greater rate of increase of chamber height.

The Brittons Swamp occurrence is in samples other than 84480.

Occurrence: (a) Great Musselroe Bay - 84482(r); (b) Preservation Island - 84479(r); (c) Brittons Swamp; (d) Redpa - 84095(v); (e) Cape Barren Island - 84554(r); (f) Marrawah district - 84111(r), 84114(r), 84115(r), 84104(f), 84101(q).

Age: Early Miocene, N4-N8.

Superfamily ORBITOIDACEA
Family LEPIDOCYCLINIDAE
Genus *LEPIDOCYCLINA* Gümbel, 1870
Lepidocyclina howchini Chapman and Crespin, 1932
(Pl.4, fig.8)

Lepidocyclina howchini Chapman and Crespin 1932: *Proc. R. Soc. Vict.* n.s. 44: 94, pl.13, figs 18,19.
L. howchini; Carter 1964, p.137, pl.17, figs 290-292.
L. howchini; Lindsay 1969: *Bull. geol. Surv. S. Aust.* 42: pl.2, fig.10.
L. howchini; Cooper 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.5.

An extensive synonymy of this species is too long to give here. For more details see the references cited by Carter (1964).

Type locality and stratigraphic level - 24-26 m Hamilton Bore, Victoria; Early Miocene.

Banks in Hughes (1957, p.72) stated that *Lepidocyclina* occurs in limestone in the Redpa district (his locality A, fig.45). I visited this area and sampled an outcrop over 6 m thick quite closely but found no *Lepidocyclina*. Chapman in Nye (1941) did not list *Lepidocyclina* from the Marrawah district, although I found it in each of four samples studied from Banks' (1957 *op. cit.*) locality E. Only two (84101, 84104) are recorded here.

Occurrence: (a) Redpa - (Banks, 1957); (b) Marrawah district - 84114(c), 84115(c), 84104(v), 84101(r).

Age: Early Miocene, N8.

Superfamily CASSIDULINACEA
Family ANNULOPATELLINIDAE
Genus *ANNULOPATELLINA* Parr and Collins, 1930
Annulopatellina annularis (Parker and Jones), 1860
(Pl.4, fig.9)

Orbitolina annularis Parker and Jones 1860: *Ann. Mag. nat. Hist.* ser.3, 6: 31.
Patellina annularis (Parker and Jones): Parker and Jones, 1865: *Phil. Trans. R. Soc.* 155: 438.
Annulopatellina annularis (Parker and Jones); Parr and Collins, 1930: *Proc. R. Soc. Vict.* n.s. 43: 93, pl.4, figs 8-10.

Type locality and stratigraphic level - Australian shore sands; Holocene.

Occurrence: Fossil Bluff - 84010a(v).

Age: Early Miocene, N4.

Family CASSIDULINIDAE
Genus *CASSIDULINA* d'Orbigny, 1826
Cassidulina laevigata d'Orbigny, 1826
(Pl.4, figs 10-11)

Cassidulina laevigata d'Orbigny 1826: *Annls Sci. nat.* ser.1, 7: 282, pl.15, figs 4-5.
C. laevigata; Howchin 1889: *Trans. Proc. R. Soc. S. Aust.* 12: 8.
C. laevigata; Chapman 1910: *Proc. R. Soc. Vict.* 22: 275.
C. laevigata; Heron-Allen and Earland 1924: *J. R. microsc. Soc.* (1924): 145.
C. laevigata; Crespin 1943, p.77.
C. laevigata; Reed 1965, p.69.
C. laevigata; Hayward and Buzas 1979, p.46, pl.7, fig.90.

Type locality and stratigraphic level - not given.

Two different species are included under this taxon here. The more common type is very close to d'Orbigny's type figure, but has more depressed sutures than in the figures given by Loeblich and Tappan (1964, p.C737, fig.604, 1).

The other species included here is found only in the limestone at Brittons Swamp and seems identical to a specimen figured by Hornibrook (1961, pl.10, fig.99) as *C. laevigata*.

Occurrence: (a) Great Musselroe Bay - 84481(v), 84482(r); (b) Mt Cameron West - 84118 (v); (c) Brittons Swamp - 84480(v); (d) Marrawah district - 84092(r), 84561 (q), 84110(v), 84104(v), 84105(v), 84106(r).

Age: Early Miocene, N4-N8.

Cassidulina neocarinata Thalmann, 1950
(Pl.4, fig.12)

Cassidulina laevigata; Brady 1884: "CHALLENGER" EXPEDN SCIENT. RESULTS ZOOL. 9: 428, pl.54, figs 2,3.
C. laevigata var. *carinata* Cushman 1922: *Bull. U.S. natn. Mus.* 104: 124, pl.25, figs 6,7.
C. neocarinata Thalmann 1950: *Contr. Cushman Fdn foramin. Res.* 1: 44.
C. caribeana Redmond 1952, p.729, pl.77, fig.6.

Type locality and stratigraphic level - Ragged Key, Florida; Holocene.

This identification is tentative. The species figured by Brady and Cushman is carinate, but Redmond's species is only sometimes carinate and his figures show a specimen with almost rounded margins. The present species is identical with the lateral aspects figured by Brady (1884) and with a section very much like that figured by Redmond (1952).

Occurrence: (a) Great Musselroe Bay - 84483(v), 84482(v); (b) Fossil Bluff - 84015(r), 84019(v), 84025a(r), 84024(v); (c) Granville Harbour - 54144(r); (d) Marrawah district - 84113(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Cassidulina translucens Cushman and Hughes, 1925
(Pl.4, figs 13,14)

Cassidulina translucens Cushman and Hughes 1925: *Contr. Cushman Lab. foramin. Res.* 1: 15, pl.2, fig.5.

Type locality and stratigraphic level - Lomita Quarry, Palos Verdes Hills, Los Angeles, California; Pleistocene.

Specimens from Tasmania have all the main characteristics of *C. translucens*, such as carinate margin, elongate, straight-sided chambers which expand distally, etc. However it is not quite as inflated as the type figures suggest and the identification is thus a little tentative.

Occurrence: (a) Fossil Bluff - 84010b(v); (b) Cape Grim - 84008(v), 84006(r), 84003 (v); (c) Granville Harbour - 54144(r); (d) Redpa - 84097(r), 84093(r), 84096(q); (e) Marrawah district - 84113(v).

Age: Early Miocene, N4-N8.

Genus *CASSIDULINOIDES* Cushman, 1927

Carter (1964, pp.70,71) recorded three species of this genus from Victorian rocks with faunas belonging to Faunal Units 4-11. On p.147, he listed these species in a morphological series. In the light of time ranges recorded here, the concept of time ranges and evolutionary relationships of these species needs revision. In Tasmania, Carter's *C. aequilatera* (included here in *C. chapmani*) ranges from F.U. 6 to F.U. 9, *C. campana* (as defined by Carter) from F.U. 6 to F.U. 9 and *C. chapmani* (here recorded as *C.* sp. A) within F.U. 7 and F.U. 8. Thus all three species coexisted for much of their geological life.

All three species found here were sectioned and seem to show a granular perforate wall structure. The genus *Cassidulinoides* is therefore placed in the Cassidulinidae.

The three species regarded by Carter (1964) and referred to him to *C. aequilatera*, *C. campana* and *C. chapmani* Parr are found in Tasmania. However, his terminology is not followed completely here. The specimen figured and described by him as *C. aequilatera* is

very similar to Parr's (1931) figures of *C. chapmani*, and also to a specimen figured by Chapman, Parr and Collins (1934, pl.10, figs 28a-c). *C. campana* is clearly different and is recorded here as such. However the specimen figured as *C. chapmani* bears very little resemblance to the type figure and description of that species and very little to Carter's description. It seems more similar to a juvenile specimen of *C. campana*.

In this work three species are recorded — *C. campana* (in the sense that Carter defined it), *C. chapmani* (including *C. aequilatera*) and *C.* sp. A, the latter probably different from the others and doubtfully separable from *Cassidulina*. This may be the species regarded by Carter as *C. chapmani*.

Cassidulinoides campana Carter, 1964
(Pl.4, figs 15-17)

Cassidulinoides campana Carter 1964, p.69, pl.2, figs 43-45.

Type locality and stratigraphic level - west side of Bell Headland, Torquay, Victoria; mid Oligocene.

Occurrence: (a) Great Musselroe Bay - 84482(v); (b) Fossil Bluff - 84024(r); (c) Cape Grim - 84008(v), 84006(f); (d) Mt Cameron West - 84118(v); (e) Redpa - 84097(v); (f) Marrawah district - 84092(v), 84561(r), 84113(r), 84114(v), 84104(v).

Age: Early Miocene, N4-N8.

Cassidulinoides chapmani Parr, 1931
(Pl.4, fig.18)

Cassidulinoides chapmani Parr 1931: *Victorian Nat.* 48: 99-100, figs a-c.
C. chapmani; Parr 1932: *Proc. R. Soc. Vict.* n.s., 44: 231, pl.22, figs 36,37.
C. chapmani; Chapman, Parr and Collins 1934, p.560, pl.10, figs 28a-c.
C. chapmani; Crespin 1943, p.78.
C. aequilatera Carter 1964, p.70, pl.2, figs 40-42.

Type locality and stratigraphic level - Rocky Point, Torquay, Victoria, soapy clay bed below echinoid band; "Miocene".

Occurrence: (a) Great Musselroe Bay - 84483(r), 84481(v), 84482(v); (b) Fossil Bluff - 84010a(r), 84017(q), 84023(q), 84025a(r), 84024(v), 84025b(v); (c) Cape Grim - 84008(v), 84006(r), 84005(r); (d) Mt Cameron West - 84121(v); (e) Granville Harbour - 54144(r); (f) Brittons Swamp - 84480(r); (g) Marrawah district - 84114(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Cassidulinoides sp. A

Occurrence: (a) Cape Grim - 84006(f); (b) Granville Harbour - 54144(r); (c) Brittons Swamp - 84480(v); (d) Redpa - 84097(r), 84093(r), 84095(v), 84096(v); (e) Marrawah district - 84113(r).

Age: Early Miocene, N4-N8.

Genus *EHRENBERGINA* Reuss, 1850
Ehrenbergina healyi Finlay, 1947
(Pl.4, figs 19,20)

Ehrenbergina healyi Finlay 1947: *N.Z. J. Sci. Technol.* 28: 284, pl.7, figs 106-115.
E. healyi; Hornibrook 1961, p.87.
E. osbornei Finlay; Reed 1965, p.69.

Type locality and stratigraphic level - 15 km south of Mt Horrible, New Zealand; Early Miocene.

Occurrence: Marrawah district - 84110(r), 84111(r), 84101(v), 84106(r).

Age: Early Miocene, N8.

Ehrenbergina serrata Reuss, 1850
(Pl.4, figs 21,22)

Ehrenbergina serrata Reuss 1850: *Denkschr. Akad. Wiss., Wien* 1: 377, pl.48, fig.7.
E. serrata; Howchin 1889, p.8.
E. serrata; Chapman 1907: *J. Linn. Soc.* 30: 33, pl.4, figs 85-87.
E. serrata; Chapman 1910: *Proc. R. Soc. Vict.* n.s., 22: 276, 303.
E. serrata; Crespin 1943, p.79.

Type locality and stratigraphic level - Baden bei Wien, Germany; "Tertiary".

This form is separated from *E. healyi* by the presence of lateral grooves and spines which give the test a serrated margin.

Occurrence: Great Musselroe Bay - 84483(v).

Age: Late Oligocene, N3.

Genus *GLOBOCASSIDULINA* Voloshinova, 1960
Globocassidulina subglobosa (Brady), 1881
(Pl.4, figs 23,24)

Cassidulina subglobosa Brady 1881: *J. R. microsc. Soc.* n.s., 21: 60.
C. subglobosa; Brady 1884: "CHALLENGER" EXPEDN SCIENT. RESULTS, ZOOL. 9: 430, pl.54, fig.17.
C. subglobosa; Howchin 1889, p.8.
C. subglobosa; Howchin 1891, p.351.
C. subglobosa; Chapman 1907: *J. Linn. Soc.* 30: 33, pl.4, fig.84.
C. subglobosa; Chapman 1910: *Proc. R. Soc. Vict.* n.s., 22: 275.
C. subglobosa; Crespin 1943, p.78.
C. subglobosa; Reed 1965, p.69.
Globocassidulina subglobosa; Hayward and Buzas 1979, p.59, pl.17, figs 219,220.

Type locality and stratigraphic level - not given. Figured specimen from "Challenger" station 120, 34°28'W, 8°37'S, off Brazil; Holocene.

Occurrence: (a) Great Musselroe Bay - 84483(f), 84481(c), 84482(f); (b) Fossil Bluff - 84010a(q), 84010b(f), 84011(r), 84012(r), 84013(v), 84014(r), 84016(a), 84017(a), 84019(c), 84021(a), 84022(f), 84023(a), 84025a(a), 84024(f), 84025b (c); (c) King Island - 84084(f), 84085(q), 84081(f), 84082(f), 84083(f), 84086(q), 84087(f), 84475(f), 84476(a), 84477(a); (d) Daisy Creek - 84478(c); (e) Cape Grim - 84008(v), 84006(r), 84005(r), 84001(v); (f) Mt Cameron West - 84118(a+), 84121(a), 84120(c), 84117(r); (g) Granville Harbour - 54144(c); (h) Preservation Island - 84479(r); (i) Brittons Swamp - 84480(q);

(j) Cape Barren Island - 84554(q); (k) Redpa - 84097(v), 84093(f), 84094(q), 84095(f), 84096(v); (l) Marrawah district - 84092(a), 84561(c), 84109(a), 84110(a), 84111(a), 84113(c), 84114(c), 84104(c), 84101(f), 84105(a), 84106(a), 84107(a).

Age: Late Oligocene-Early Miocene, N3-N8.

Superfamily NONIONACEA
Family NONIONIDAE
Subfamily NONIONINAE
Genus *ASTRONONION* Cushman and Edwards, 1937
Astrononion australe Cushman and Edwards, 1937
(Pl.5, fig.1)

Astrononion australe Cushman and Edwards 1937: *Contr. Cushman Lab. foramin. Res.* 13: 33, pl.3, figs 13,14.
A. australe; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 37,38, pl.10, figs 7,8.
A. australe; Crespin 1943, p.77.
A. australe; Carter 1958, p.60, pl.9, figs 91,92.
A. australe; Carter 1964, p.111, pl.11, fig.207.
A. australe; Hornibrook 1964: *Micropaleontology* 10: 335.
A. australis; Reed 1965, p.70.

Type locality and stratigraphic level - Muddy Creek, Victoria; Middle Miocene.

Occurrence: (a) Great Musselroe Bay - 84482(v); (b) Fossil Bluff - 84013(v), 84014(r), 84015(r); (c) Cape Grim - 84001(v); (d) Mt Cameron West - 84118(v); (e) Marrawah district - 84107(v).

Age: Early Miocene, N4-N8.

Astrononion centroplax Carter, 1958
(Pl.5, figs 2,3)

Astrononion centroplax Carter 1958, p.61, pl.9, figs 95-97.
A. centroplax; Carter 1964, p.36.
A. centroplax; Reed 1965, p.70.
A. centroplax; Cooper 1979: *Rept Invest. geol. Surv. S. Aust.* 50: pl.19, fig.11.

Type locality and stratigraphic level - Aire coast, Victoria; Late Oligocene.

The species is recorded in sediments here as young as Faunal Unit 9. Previous records (e.g. Carter 1958, 1964) record it as high as Faunal Unit 8 only. Although poorly preserved, it is recorded here in samples with *Lepidocyclina howchini* (84104, 84114).

Occurrence: (a) Great Musselroe Bay - 84483(v), 84481(v), 84482(r); (b) Fossil Bluff - 84010a(r), 84010b(r), 84011(r), 84012(r), 84013(v), 84014(v), 84019(r), 84024 (v); (c) King Island - 84084(v); (d) Daisy Creek - 84478(r); (e) Mt Cameron West - 84118(q), 84121(v), 84120(r); (f) Preservation Island - 84479(v); (g) Brittons Swamp - 84480(v); (h) Marrawah district - 84092(r), 84561(r), 84110(r), 84113(r), 84114(r), 84104(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Astrononion tasmaniensis Carter, 1964
(Pl.5, figs 4,5)

Astrononion novo-zealandicum Cushman and Edwards 1937: *Contr. Cushman Lab. foramin. Res.* 13: 35, pl.3, figs 18a,b.
Nonion novozealandicus; Howchin and Parr 1938: *Trans. R. Soc. S. Aust.* 62: 308, pl.18, fig.15.
Astrononion novo-zealandicum; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 36, pl.10, fig.12.
A. tasmaniensis Carter 1964, p.111, pl.10, figs 203,204.
A. novozealandicum; Hornibrook 1964: *Micropaleontology* 10: 335, pl.1, fig.20.

Type locality and stratigraphic level - Rose Hill, Mitchell River, Victoria; Late Miocene.

Following Carter (1964), this name is given to *Astrononion novozealandicum* Cushman and Edwards 1937, a subjective homonym of *Nonion novozealandicum* Cushman 1936. The latter species is regarded, probably correctly, by Carter as an *Astrononion*. It seems worth noting that the original spelling of the trivial name of both homonyms was *novozealandicum*, not *novozelandicum* as recorded by Carter.

The record from Great Musselroe Bay appears to be the earliest so far.

Occurrence: (a) Great Musselroe Bay - 84483(v), 84481(v); (b) Fossil Bluff - 84010a(r), 84010b(q), 84011(f), 84012(r), 84013(q), 84014(f), 84015(f), 84017(q), 84019 (f), 84021(f), 84022(f), 84023(q), 84025a(q), 84024(q), 84025b(r); (c) Cape Grim - 84008(v), 84006(v), 84003(v), 84001(v); (d) Brittons Swamp - 84480(r); (e) Marrawah district - 84561(r), 84104(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Genus *FLORILUS* de Montfort, 1808
Florilus victoriense (Cushman), 1936
(Pl.5, fig.6)

Nonion victoriense Cushman 1936: *Contr. Cushman Lab. foramin. Res.* 12: 67, pl.12, figs 10a,b.
N. victoriense; Cushman 1939: *Prof. Pap. U.S. geol. Surv.* 191: 17, pl.4, fig.14.
N. victoriense; Parr 1939: *Min. geol. J.* 1: 69, pl.1, fig.20.
N. victoriense; Crespin 1943, p.81.
N. victoriense; Carter 1964, p.109, pl.10, figs 201,202.
N. victoriense; Reed 1965, p.70.

Type locality and stratigraphic level - near Lake Bunga, eastern Victoria; Pliocene.

This species is transferred to *Florilus* de Montfort, as it fits the diagnosis of that genus better than that of *Nonion*. *Nonion* includes those species with a slower rate of increase of chamber height than shown in this group. The difference in amount is shown clearly in the figures of the respective genera in Loeblich and Tappan (1964, p.C745).

Occurrence: (a) Fossil Bluff - 84010a(v), 84010b(r), 84011(v), 84012(r), 84013(r), 84014(c), 84015(q), 84016(q), 84017(r), 84019(r), 84021(f), 84022(r), 84023(r), 84025a(v), 84024(v); (b) Cape Grim - 84008(v).

Age: Early Miocene, N4.

Genus *PULLENIA* Parker and Jones, 1862
Pullenia bulloides (d'Orbigny), 1846

Nonionina sphaeroides d'Orbigny, 1826: *Annls Sci. nat.* ser.1, 7: 293 (*nom. nud.*).
N. bulloides d'Orbigny, 1846: FORAMINIFERES FOSSILES DU BASSIN TERTIARE DE VIENNE (Gide and Co.: Paris): 107, pl.5, figs 9,10.
Pullenia bulloides (d'Orbigny); Karrer 1868: *Sber. Akad. Wiss., Wien* 58: 172.
P. sphaeroides (d'Orbigny); Howchin 1891, p.352.
P. sphaeroides; Chapman, Parr and Collins 1934, p.568, pl.10, figs 30a-b.
P. sphaeroides; Crespin 1943, p.82.
P. bulloides; Cushman and Todd 1943: *Contr. Cushman Lab. foramin. Res.* 19: 13, pl.12, figs 15-18.
P. bulloides; Hayward and Buzas 1979, p.72, pl.24, figs 303,304.

Type locality and stratigraphic level - not given.

Occurrence: (a) Great Musselroe Bay - 84482(v); (b) Fossil Bluff - 84025a(v), 84024(v); (c) King Island - 84084(v), 84081(v), 84087(q); (d) Cape Grim - 84008(v); (e) Marrawah district - 84561(v).

Age: Early Miocene, N4.

Pullenia miocenica Kleinpell, 1938
(Pl.5, figs 7,8)

Pullenia miocenica Kleinpell, 1938: MIOCENE STRATIGRAPHY OF CALIFORNIA (Am. Assoc. Petrol. Geol.: Tulsa): 338, pl.14, fig.6.
P. miocenica; Carter 1964, p.71, pl.2, figs 46-47.

Type locality and stratigraphic level - LSJU Locality 691, Reliz Canyon, Monterey County, California; Lower Luisian.

Carter (1964) regarded *Pullenia sphaeroides* as recorded by Chapman, Parr and Collins (1934, p.568) and Crespin (1943, p.82) as synonymous with *P. miocenica*. Chapman *et al.* figured a specimen and the figure is of a species more inflated than *P. miocenica* and with only four chambers in the last whorl. It seems more likely that it is *P. bulloides* than *P. miocenica*. Also, as *P. sphaeroides* and *P. bulloides* are now regarded as synonyms, it seems more likely that these records refer to *P. bulloides* (*q.v.*).

Occurrence: (a) Mt Cameron West - 84120(v); (b) Marrawah district - 84107(v).

Age: Early Miocene, N4, N8.

Pullenia quinqueloba (Reuss), 1851
(Pl.5, fig.9)

Nonionina quinqueloba Reuss, 1851: *Z. dt. geol. Ges.* 3: 71, pl.5, fig.31.
Pullenia quinqueloba; Howchin 1891, p.352.
P. quinqueloba; Heron-Allen and Earland 1924: *J. R. microsc. Soc.* (1924): 166.
P. quinqueloba; Chapman, Parr and Collins 1934, p.568, pl.10, figs 29a,b.
P. quinqueloba; Crespin 1943, p.82.
P. quinqueloba; Cushman and Todd 1943: *Contr. Cushman Lab. foramin. Res.* 19: 10,11, pl,2, fig.5; pl.3, fig.8.
P. quinqueloba; Carter 1958, p.32, pl.2, figs 8,9.
P. quinqueloba; Carter 1964, p.71.
P. quinqueloba; Reed 1965, p.69.

Type locality and stratigraphic level - Hemsdorf, Germany; Eocene.

Occurrence: (a) Great Musselroe Bay - 84481(r); (b) Fossil Bluff - 84010b(v), 84011 (v), 84012(v), 84013(v), 84017(r), 84019(v); (c) Marrawah district - 84104(v).

Age: Early Miocene, N4, N8.

Pullenia salisburyi R.E. and K.C. Stewart, 1930
(Pl.5, fig.10)

Pullenia salisburyi R.E. and K.C. Stewart, 1930: *J. Paleont.* 4: 72, pl.8, fig.2.
P. salisburyi; Cushman and Todd 1943: *Contr. Cushman Lab. foramin. Res.* 19: 20, pl.3, figs 10,11.

Type locality and stratigraphic level - Mud pits at the Dent Mud Plant about 3 km north of Ventura, and 600 m east of Ventura Avenue at the head of Franklin Lane, Ventura County, California; Pliocene.

Occurrence: Fossil Bluff - 84010b(v), 84011(v).

Age: Early Miocene, N4.

Family ALABAMINIDAE
Genus *ALABAMINA* Toulmin, 1941
Alabamina tenuimarginata (Chapman, Parr and Collins), 1934
(Pl.5, figs 11,12)

Pulvinulinella tenuimarginata Chapman, Parr and Collins, 1934: *J. Linn. Soc.* 38 (262): 565, pl.9, fig.19.
P. tenuimarginata; Crespin 1943, p.82.
Alabamina tenuimarginata; Carter 1964, p.114, pl.11, figs 220-222.
A. tenuimarginata; Reed 1965, p.69.
A. tenuimarginata; Hayward and Buzas 1979, p.38, pl.4, fig.41.

Type locality and stratigraphic level - Kackeraboite Creek, Port Phillip area, Victoria; Oligocene.

Occurrence: (a) Great Musselroe Bay - 84482(v); (b) Cape Grim - 84006(v); (c) Marrawah district - 84113(r), 84114(r), 84104(q), 84106(r).

Age: Early Miocene, N4, N8.

Genus *GYROIDINA* d'Orbigny, 1826

Loeblich and Tappan (1964) placed *Gyroidina* in the Alabaminidae and *Gyroidinoides* in the Osangulariidae without having the knowledge of the wall structure of the type species of *Gyroidina* (*G. orbicularis*). Thus there seems little basis for placing them definitively in separate families. Generic differentiation was based on *Gyroidinoides* having an aperture along the entire base of the apertural face whereas in *Gyroidina* it is restricted to a small central point at the base of the apertural face and this difference in apertural character was also taken as the basis for a family differentiation. In my experience some species show all gradations from small *Gyroidina* type apertures to longer *Gyroidinoides* type and it is my opinion that the differentiation of two genera is unnecessary, until some wall structure difference can be proven. Thus all are included here in *Gyroidina*. Hayward and Buzas (1979) seem to have adopted the same procedure.

In the Tasmanian samples, *Gyroidina* can be divided into two groups:
(a) those with 10-11 chambers per whorl which are identified as *G. allani* Finlay and are commonly well preserved, and
(b) those specimens with fewer chambers per whorl, and with a less rounded margin to the dorsal surface: these are often poorly preserved and are identified as *G. zelandica* Finlay, although this group may also contain some *G. neosoldanii* Brotzen.

Gyroidina allani Finlay, 1939
(Pl.5, figs 13-18)

Gyroidina zelandica Finlay, 1939: *Trans. R. Soc. N.Z.* 69: 323, pl.28, figs 134-136.
Gyroidinoides allani; Hornibrook 1961, p.112, pl.16, figs 340-342.
G. allani; Reed 1965, p.77.

Type locality and stratigraphic level - Otiake, North Otago, New Zealand; Late Oligocene.

Hornibrook (1961) recorded this species only in rocks as young as Late Oligocene, but Reed (1965) found it in Early Miocene rocks in the Heywood bore, Victoria. The latter occurrence is in keeping with its occurrence here.

Two specimens of *G. allani* are figured. One is a typical specimen, large, with about 11 chambers in the final whorl and a proloculus diameter of about 0.04 mm. The other specimen is much smaller, has only about six to seven chambers in the final whorl and has a proloculus diameter of 0.08 mm, the large proloculus being very prominent. The smaller specimens made up 50% of a sample of *G. allani* from Cape Grim (84008). Overall, the specimens with the small proloculus (microspheric?) are more abundant than the "megalospheric", so the smaller specimens may represent a new species as it is very seldom that the microspheric generation is the dominant one.

Occurrence: (a) Cape Grim - 84008(r), 84007(r), 84006(r), 84005(v), 84001(v);
(b) Mt Cameron West - 84120(r); (c) Marrawah district - 84561(f).

Age: Early Miocene, N4.

Gyroidina neosoldanii Brotzen, 1936
(Pl.5, figs 21-23)

Gyroidina neosoldanii Brotzen, 1936: *Sverig. geol. Unders. Arh.* 30(3), ser.C, no.396: 158.
Gyroidinoides neosoldanii (Brotzen); Hornibrook 1961, p.112, pl.16, figs 338,343.

Type locality and stratigraphic level - "Challenger" Station 302, 82°11'W, 42°43'S; Holocene.

Occurrence: Marrawah district - 84561(v).

Age: Early Miocene, N4.

Gyroidina prominula (Stache), 1864
(Pl.5, figs 19,20)

Rotalia soldanii d'Orbigny var. *prominula* Stache, 1864: "NOVARA" EXPEDN, GEOL. THEIL. 1(2): 274, pl.24, fig.24.
Gyroidina prominula; Hornibrook 1961, p.111, pl.16, figs 348,349.

Type locality and stratigraphic level - Raglan Harbour, New Zealand; Early Oligocene.

The name is used for the species described under this name by Hornibrook (1961). However, the same is strictly a *nomen dubium* following Hornibrook (1971).

Occurrence: Marrawah district - 84561(r).

Age: Early Miocene, N4.

Gyroidina zelandica Finlay, 1939
(Pl.6, figs 1-3)

Gyroidina zelandica Finlay, 1939b, p.323, pl.28, figs 138-140.
Gyroidinoides zelandica; Hornibrook 1961, p.113, pl.16, figs 339,344.
G. zelandicus; Reed 1965, p.69.
Gyroidina zelandica; Hayward and Buzas 1979, p.60, pl.18, figs 221-223.

Type locality and stratigraphic level - Island Creek, Tutamoe, New Zealand; Miocene.

More than one species of the *G. zelandica* lineage may be included here, but the preservation generally is not good and finer subdivision is impossible.

Occurrence: (a) King Island - 84085(r), 84081(v); (b) Mt Cameron West - 84118(v); (c) Marrawah district - 84092(q), 84109(q), 84110(r), 84111(q), 84113(r), 84104(r), 84101(v), 84106(r), 84107(r).

Age: Early Miocene, N4-N8.

Family ANOMALINIDAE
Subfamily ANOMALININAE
Genus *ANOMALINA* d'Orbigny, 1826
Anomalina cf *humilis* (Brady), 1884
(Pl.6, figs 4,5)

Truncatulina humilis Brady, 1884, p.665, pl.94, figs 7a-c.

Type locality and stratigraphic level - not designated. Localities given - North Atlantic and North Pacific Ocean; Holocene.

This species occurs in two Cape Grim samples [84008(v), 84006(v)] and only one specimen was found in each. The closest figured species appears to be that listed here, but the specimens may well be unusual forms of *Anomalinoides macraglabrus* or *A. nonionoides*. The generic name follows Thalmann (1932). The umbilical details in Brady's figures are not clear enough to allow positive comparison.

Age: Early Miocene, N4.

Anomalina sp.1
(Pl.6, figs 6-8)

A single unidentified specimen is referred to this genus. The appearance of the wall is typical of *Anomalina* or *Anomalinoides*, but the apertural details are obscure. The specimen has seven chambers in the final whorl, no umbilicus at all and is little compressed.

Occurrence: Marrawah district - 84113(v).

Age: Early Miocene, N8.

Genus *ANOMALINOIDES* Brotzen, 1942

The main part of the Tasmanian *Anomalinoides* can be broken down into two groups:
(a) those specimens with a clear thickened central part of the dorsal surface and in which the early whorls are clearly visible (examples are *A. pinguiglabrus* and *A. macraglabrus*).
(b) those specimens which have a considerably thickened opaque central area on the dorsal surface and in which early whorls are not visible (an example is *A. nonionoides*). Members of this group generally have a thicker, more coarsely perforate wall and more lobulate periphery than members of group (a).

The species of these groups are generally distinguished to a large extent on the number of chambers in the final whorl. All the specimens are referred to *Anomalinoides* because in any population, the aperture passes onto the dorsal surface in many specimens.

Anomalinoides macraglabrus (Finlay), 1940
(Pl.6, figs 9,10)

Anomalina glabrata Cushman; Chapman, Parr and Collins 1934, p.570, pl.11, figs 39a-c.
A. macraglabra Finlay, 1940: *Trans. R. Soc. N.Z.* 69: 460, pl.65, figs 141-143.
A. glabrata; Crespin 1943, p.77.
Anomalinoides macraglabra; Hornibrook 1961, p.155, pl.24, figs 473-475.
Anomalina macraglabra; Carter 1964, p.99, pl.8, figs 151-153.
A. macraglabra; Reed 1965, p.70.
Anomalinoides macraglabrus; Hayward and Buzas 1979, p.40, pl.5, figs 52,53.

Type locality and stratigraphic level - Kakanui Beach, New Zealand; Early Miocene.

The dominant species of *Anomalinoides* in Tasmania is that referred by Carter (1964 *op. cit.*) to *Anomalina macraglabra* Finlay. However, the description of *A. macraglabra* does not include all the variations found in a large sample. To give some idea of the variation in number of chambers in the final whorl, the Fossil Bluff samples were examined individually. The samples had between 13 and 70 specimens of the species in each. The results of final whorl chamber counts for each sample are shown in figure 3, in which each sample has been statistically reduced to a size of about 20 (13-28) to make comparison simpler. An average specimen has between eight and ten chambers in the final whorl with a range from 5-13. In most samples, results fit a unimodal histogram. Sample 84011 shows two peaks, perhaps suggesting separation into micro- and megalospheric generations. Many smaller specimens have only one whorl and often have a larger proloculus. However, a simple alternation-of-generations hypothesis does not explain it all, as many small specimens have two whorls and a small proloculus.

Thus, in this work, *A. macraglabrus* is interpreted more widely than by Carter (1964), who suggested that the species has 12 chambers in the final whorl, or by Finlay (1940), who suggested 10 to 11. An average specimen recovered here has between eight and ten chambers in the final whorl.

In several cases, the variation of the species is wide enough to include the robust species *A. pinguiglabrus* (Finlay). It may also include *A. parvumbilius* (Finlay). In the samples studied, the very rare specimens referable to *A. pinguiglabrus* are recorded as *A. macraglabrus*. In the Redpa, Marrawah and Mt Cameron West samples, identification is a little tentative and some specimens may be *A. nonionoides*.

Occurrence: (a) Great Musselroe Bay - 84482(r); (b) Fossil Bluff - 84010a(f), 84010b(f), 84011(f), 84012(f), 84013(q), 84014(a), 84015(c), 84016(c), 84017(f), 84019(c), 84021(f), 84022(q), 84023(q), 84025a(q), 84024(r), 84025b(c); (c) Cape Grim - 84008(v); (d) Mt Cameron West - 84118(v), 84121(r), 84120(q); (e) Granville Harbour - 54144(q); (f) Redpa - 84097(q), 84093(r), 84094(r), 84095(r), 84096(v); (g) Marrawah district - 84561(r), 84109(r), 84110(v), 84113(r), 84104(r), 84106(r), 84107(r).

Age: Early Miocene, N4-N8.

Anomalinoides nonionoides (Parr), 1932
(Pl.6, figs 11-13)

Anomalina nonionoides Parr, 1932: *Proc. R. Soc. Vict.* n.s., 44: 231, pl.22, figs 38a-c.
A. nonionoides; Crespin 1943, p.77.
A. nonionoides; Carter 1964, p.100, pl.8, figs 154-156.

Type locality and stratigraphic level -- Station 7, Narrabeen, New South Wales; Holocene.

In some instances, misidentification of this species for *A. macraglabrus* may have occurred in samples from Mt Cameron West and the Marrawah district where preservation is poor.

Occurrence: (a) Great Musselroe Bay - 84483(q), 84481 (r); (b) Fossil Bluff - 84010b(v), 84019(q); (c) King Island - 84475(q), 84476(f), 84477 (f); (d) Cape Grim - 84008(v), 84007(r), 84006(r), 84005 (r), 84003(q), 84001(r); (e) Mt Cameron West - 84121(r); (f) Cape Barren Island - 84554(r); (g) Marrawah district - 84092(q), 84561(f), 84110(r), 84114(r), 84101(r), 84105(r).

Age: Late Oligocene-Early Miocene, N3-N8.

Anomalinoides cf *planulatus* Carter, 1964
(Pl.6, figs 14,15)

?Cibicides lobatulus (Walker & Jacob); Chapman, Parr and Collins 1934, p.570, pl.11, figs 41a-c.
?Anomalinoides planulatus Carter 1964, p.99, pl.8, figs 148-150.

Type locality and stratigraphic level (*A. planulatus*)- Skinner's, Mitchell River, Victoria; Early Miocene.

A few very poorly preserved specimens, quite similar to Chapman, Parr and Collins' (1934, *op. cit.*) figures, are found in Tasmania.

Occurrence: (a) King Island - 84084(q), 84081(v), 84086(r); (b) Redpa - 84095(v).

Age: Early Miocene, N4, N8.

Anomalinoides subnonionoides (Finlay), 1940
(Pl.6, figs 16,17)

Anomalina subnonionoides Finlay, 1940: *Trans. R. Soc. N.Z.* 69: 459, pl.66, figs 172-180.
Anomalinoides subnonionoides; Hornibrook 1961, p.155, pl.23, figs 467-469.

Type locality and stratigraphic level - Kakanui Beach, New Zealand; Early Miocene.

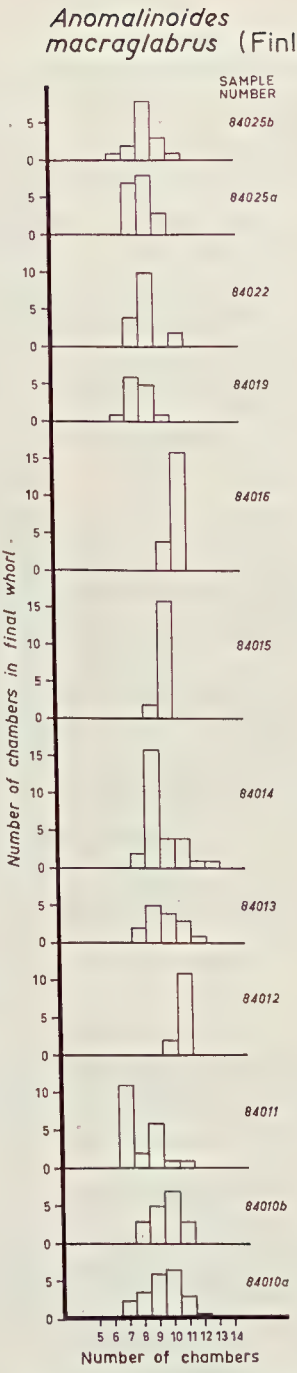

FIG.3 - Chamber counts for *Anomalinoides macraglabra* at various levels in the Fossil Bluff section.

Occurrence: Cape Barren Island - 84554(v).

Age: Early Miocene, N8.

Anomalinoides cf *sphericus* (Finlay), 1940
(Pl.6, figs 18,19)

Anomalina spherica Finlay, 1940: *Trans. R. Soc. N.Z.* 69: 460, pl.66, figs 166-171.

Type locality and stratigraphic level (*A. sphericus*) - north of Hen and Chickens, in 55 m, New Zealand; Holocene.

A few small, poorly preserved specimens from King Island are referred tentatively to this species. Following Finlay (1940) they may be stratigraphically too old to be true *A. sphericus*.

Occurrence: King Island - 84085(r), 84082(r), 84083(v).

Age: Early Miocene, N4.

Genus *HANZAWAIA* Asano, 1944
Hanzawaia procolligera (Carter), 1958
(Pl.6, figs 20,21)

Anomalina rotula d'Orbigny: Chapman, Parr and Collins 1934, p.570, pl.11, figs 38a-c.
Anomalinoides procolligera Carter 1958, p.49, pl.6, figs 60-63.
A. procolligera; Reed 1965, p.70.

Type locality and stratigraphic level - Barwon River, Birregurra, Victoria; Late Oligocene or Early Miocene.

Only five specimens were recovered, of which two are from Great Musselroe Bay. The Fossil Bluff specimen is well preserved and is figured.

Occurrence: (a) Great Musselroe Bay - 84483(v); (b) Fossil Bluff - 84011(v); (c) Mt Cameron West - 84117(r); (d) Marrawah district - 84561(r), 84110(v).

Age: Late Oligocene-Early Miocene, N3-N8.

Genus *KARRERIA* Rzehak, 1891
Karreria maoria (Finlay), 1939
(Pl.6, figs 22,23)

Vagocibicides maoria Finlay 1939b, p.326, pl.29, figs 148-151,158.
V. maoria; Carter 1964, p.90, pl.6, figs 116-120.
Karreria maoria (Finlay); Loeblich and Tappan 1964, p.C761, fig.623,9.
K. maoria; Hayward and Buzas 1979, p.61, pl.19, figs 233,234.

Type locality and stratigraphic level - East Grey River, New Zealand; Miocene/Pliocene.

Reed (1965, p.79) suggested that *Vagocibicides* is a synonym of *Cibicides*, believing it to have developed from *Cibicides* in a similar manner to *Dyocibicides*. The wall of species referable to this genus has been examined several times (e.g. Loeblich and Tappan 1964, Carter 1964), and ample evidence has been forthcoming to show that it is very different from the wall of *Cibicides*. Loeblich and Tappan (1964) placed *Vagocibicides* in synonymy of *Karreria* and their judgement is followed here.

Occurrence: (a) Great Musselroe Bay - 84483(v), 84482(v); (b) King Island - 84085(v); (c) Marrawah district - 84561(v), 84113(v), 84104(r).

Age: Late Oligocene-Early Miocene, N3-N8.

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PLATE 1

Figure in parentheses is maximum dimension of figured specimen.

FIGS 1, 2 *Eponides lornensis* Finlay, Great Musselroe Bay; UTGD 84338, x24; (1.1 mm); from UTGD 84483.

FIGS 3, 4 *Eponides repandus* (Fichtel and Moll), Great Musselroe Bay; UTGD 84339, x30; (0.9 mm); from UTGD 84483.

FIG. 5 *Siphonina australis* Cushman, Fossil Bluff; UTGD 84455, x86; (0.35 mm); from UTGD 84011.

FIGS 6, 7 *Amphistegina lessonii* d'Orbigny, Marrawah; UTGD 84351, x10; (2.55 mm); from UTGD 84113.

FIGS 8, 9 *Hyalinea* sp., King Island; UTGD 84369, x70; (0.35 mm); from UTGD 84084.

FIGS 10-12 *Crespinella parri* Quilty, Fossil Bluff; holotype, UTGD 84286; 10,11 - x40, 12 - details of aperture, x40; (0.65 mm); from UTGD 84010a.

FIGS 13, 14 *Crespinella umbonifera* (Howchin and Parr), Preservation Island; UTGD 84505, x30; (0.85 mm); from UTGD 84479.

FIGS 15-18 *Valvulineria kalimnensis* (Parr), Fossil Bluff; 15 - UTGD 84506, equatorial section, x54; (0.57 mm); 16,17 - UTGD 84470, x45; (0.6 mm); 18 - detail of supplementary sutural apertures, x120; 15 - from UTGD 84011; 16 to 18 - from UTGD 84010b.

FIGS 19, 20 *Cibicides refulgens* de Montfort, King Island; UTGD 84279, x65; (0.4 mm); from UTGD 84084.

FIGS 21, 22 *Cibicides thiara* Stache, Fossil Bluff; UTGD 84284, x80; (0.38 mm); from UTGD 84010b.

FIGS 23-25 *Cibicides vortex* Dorreen, Cape Grim; UTGD 84285, x75; (0.38 mm); from UTGD 84008.

FIGS 26, 27 *Cibicidoides brevoralis* (Carter), Fossil Bluff; UTGD 84277, x60; (0.5 mm); from UTGD 84025b.

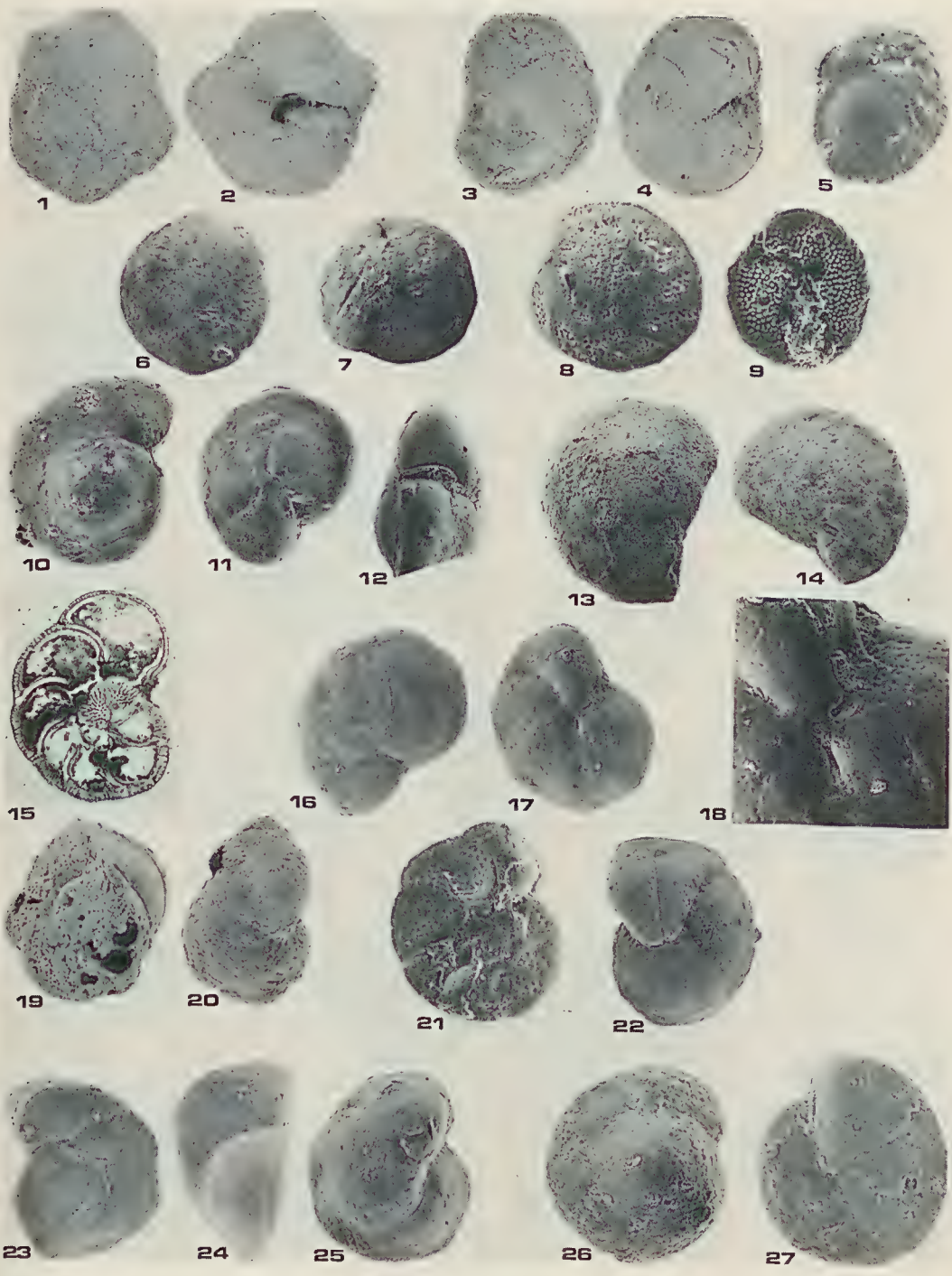

PLATE 1

PLATE 2

FIGS 1, 2 *Cibicidoides perforatus* (Karrer), Fossil Bluff; UTGD 84281, x65; (0.45 mm); from UTGD 84010b.

FIGS 3, 4 *Cibicidoides subhaidingeri* (Parr), Fossil Bluff; UTGD 84282, x85; (0.35 mm); from UTGD 84010a.

FIGS 5, 6 *Cibicidoides temperata* (Vella), Fossil Bluff; UTGD 84283, x35; (0.7 mm); from UTGD 84010b.

FIGS 7, 8 *Dyocibicides biserialis* Cushman and Valentine, Fossil Bluff; UTGD 84314, x75; (0.35 mm); from UTGD 84010b.

FIG. 9 *Planorbulina mediterranensis* d'Orbigny, Cape Grim; UTGD 84421, x50; (0.5 mm); from UTGD 84001.

FIGS 10-12 *Planorbulinella inaequilateralis* (Heron-Allen and Earland), Fossil Bluff; 10 - UTGD 84423, x25; (1.1 mm); 11,12 - UTGD 84422; Equatorial section, x22 and x160 respectively. (1.1 mm); from UTGD 84010a.

FIGS 13, 14 *Planorbulinella plana* (Heron-Allen and Earland), Marrawah; 13 - UTGD 84424, x28; (0.95 mm); from UTGD 84114. 14 - UTGD 84528 Equatorial section, x 30; (0.9 mm); from UTGD 84104.

FIG. 15 *Gypsina globulus* (Reuss), Great Musselroe Bay; UTGD 84529, x50; (0.5 mm); from UTGD 84481.

FIG. 16 *Gypsina howchini* Chapman, Cape Barren Island; UTGD 84558, x23; (1.25 mm); from UTGD 84554.

FIG. 17 *Gypsina* sp., Cape Grim; UTGD 84363, x17; (1.6 mm); from UTGD 84007.

FIGS 18, 19 *Carpenteria balaniformis* Gray, Fossil Bluff; UTGD 84572, x25; (1.4 mm); from UTGD 84010a.

FIG. 20 *Carpenteria rotaliformis* Chapman and Crespin, Great Musselroe Bay; UTGD 84267, x22; (1.2 mm); from UTGD 84483.

FIGS 21-24, 26 *Sherbornina atkinsoni* Chapman, Topotypes, Fossil Bluff; 21,22 - UTGD 84450, x21 and x 70 respectively; (1.2 mm); 23 - UTGD 121111, x 30; (1.0 mm); 24 - UTGD 84509, x35; (0.85 mm); 26 - UTGD 84508, x58; (0.95 mm); all from UTGD 84010a.

FIG. 25 *Sherbornina atkinsoni*, Brittons Swamp; UTGD 84451, x22; (1.2 mm).

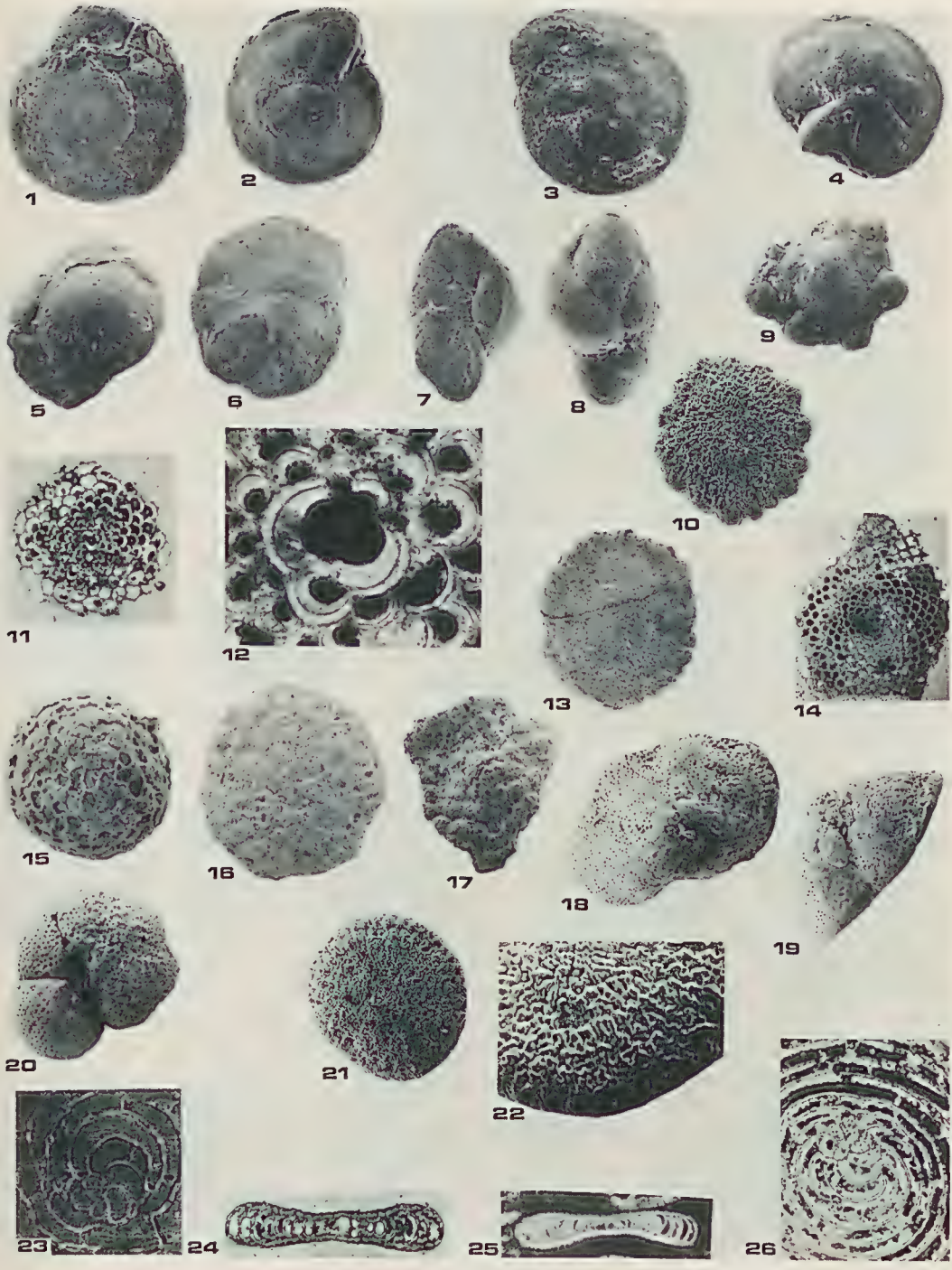

PLATE 2

PLATE 3

FIGS 1-6 *Tenisonina tasmaniae* Quilty, Cape Grim; 1-3 - Holotype, UTGD 84510; 1,2 - x23; (1.2 mm); 3 - detail of 1, x240. 4 - Paratype, UTGD 84511, equatorial section; x23, (1.2 mm); 5 - Paratype, UTGD 84512, equatorial section; x65 (0.36 mm); 6 - Paratype, UTGD 84513, vertical section, x30; (1.1 mm); all from UTGD 84005.

FIGS 7, 8 *Calcarina mackayi* (Karrer), Great Musselroe Bay; UTGD 84516, x55; (0.55 mm); from UTGD 84481.

FIGS 9, 10 *Calcarina verriculata* (Howchin and Parr), Fossil Bluff; UTGD 84263, x30; (1.1 mm); from UTGD 84010a.

FIG. 11 *Cribroelphidium poeyanum* (d'Orbigny), Fossil Bluff; UTGD 84292, x120; (0.25 mm); from UTGD 84022.

FIG. 12 *Elphidium chapmani* Cushman, Fossil Bluff; UTGD 84318, x18; (1.5 mm); from UTGD 84013.

FIG. 13 *Elphidium crassatum* Cushman, Marrawah; UTGD 84527, x45; (0.6 mm); from UTGD 84104.

FIG. 14 *Elphidium crespinae* Cushman, Great Musselroe Bay; UTGD 84319, x35; (0.8 mm); from UTGD 84482.

FIGS 15, 16 *Elphidium grimensis* Quilty, Holotype, Cape Grim; UTGD 84324, x45; (0.57 mm); from UTGD 84001.

FIGS 17, 18 *Elphidium helenae* Quilty, Holotype, Fossil Bluff; UTGD 84331, x95; (0.32 mm); from UTGD 84010b.

FIGS 19-21 *Elphidium musselroeensis* Quilty, Great Musselroe Bay; 19 - Holotype, UTGD 84332, x14; (2.0 mm); 20,21 - Paratype, UTGD 84333, equatorial section, x22 and x125 respectively; 21 - illustrates typical septal structure of *Elphidium* ; (1.2 mm); from UTGD 84483.

FIGS 22, 23 *Elphidium pseudoinflatum* Cushman, Great Musselroe Bay; UTGD 84517, x35; (0.8 mm); from UTGD 84481.

FIGS 24, 25 *Elphidium* sp. 1, Cape Grim; UTGD 84336, x95; (0.3 mm); from UTGD 84003.

FIGS 26, 27 *Elphidium* sp. 2, Cape Grim; UTGD 84317, x50; (0.57 mm); from UTGD 84008.

PLATE 3

PLATE 4

FIGS 1-3 *Notorotalia howchini* (Chapman, Parr and Collins), 1 - Fossil Bluff; x50, UTGD 84428; (0.6 mm); from UTGD 84010b. 2,3 - Great Musselroe Bay; UTGD 84427, x35; (0.9 mm); from UTGD 84483.

FIGS 4, 5 *Polystomellina miocenica* Cushman, Marrawah; UTGD 84426, x50, x60 respectively; (0.55 mm); from UTGD 84104.

FIGS 6, 7 *Operculina victoriensis* Chapman and Parr, Marrawah; 6 - UTGD 84519, equatorial section, x15; (2.2 mm); 7 - UTGD 84518, vertical section, x35; (1.1 mm); from UTGD 84104.

FIG. 8 *Lepidocyclina howchini* Chapman and Crespin, Marrawah; UTGD 84404, equatorial section, x13; (2.5 mm); from UTGD 84114.

FIG. 9 *Annulopatellina annularis* (Parker and Jones), Fossil Bluff; UTGD 84573, x65; (0.45 mm); from UTGD 84010a.

FIGS 10, 11 *Cassidulina laevigata* d'Orbigny, Brittons Swamp; UTGD 84533; 10 - x95; 11 - detail of aperture, x190; (0.3 mm); from UTGD 84480.

FIG. 12 *Cassidulina neocarinata* Thalmann, Fossil Bluff; UTGD 84269, x140; (0.21 mm); from UTGD 84025a.

FIGS 13, 14 *Cassidulina translucens* Cushman and Hughes, Cape Grim; UTGD 84270, x90; (0.32 mm); from UTGD 84008.

FIGS 15-17 *Cassidulinoides campana* Carter, Cape Grim; 15 - UTGD 84273, x75; (0.4 mm); 16, 17 - thin section in plane polarised light and under crossed polars respectively, UTGD 84274, x65; (0.4 mm); 15 - from UTGD 84008; 16, 17 - from UTGD 84006.

FIG. 18 *Cassidulinoides chapmani* Parr, Cape Grim; UTGD 84275, x90; (0.32 mm); from UTGD 84006.

FIGS 19, 20 *Ehrenbergina healyi* Finlay, Marrawah; UTGD 84315, x75; (0.4 mm); from UTGD 84106.

FIGS 21, 22 *Ehrenbergina serrata* Reuss, Great Musselroe Bay; UTGD 84316, x60; (0.55 mm); from UTGD 84483.

FIGS 23, 24 *Globocassidulina globosa* (Brady), King Island; UTGD 84360, x75; (0.40 mm); from UTGD 84097.

PLATE 4

PLATE 5

FIG. 1 *Astrononion australe* Cushman and Edwards, Cape Grim; UTGD 84254, x110; (0.25 mm); from UTGD 84001.

FIGS 2, 3 *Astrononion centroplax* Carter, Fossil Bluff; UTGD 84255; 2 - x60; (0.45 mm); from UTGD 84010b. 3 - detail of 2, x250.

FIGS 4, 5 *Astrononion tasmaniensis* Carter, Fossil Bluff; UTGD 84256, x75; (0.4 mm); from UTGD 84010b. 5 - detail of 4, x750.

FIG. 6 *Florilus victoriensis* (Cushman), Fossil Bluff; UTGD 84343, x60; (0.5 mm); from UTGD 84010b.

FIGS 7, 8 *Pullenia miocenica* Kleinpell, Mt Cameron West; UTGD 84436, x120; (0.25 mm); from UTGD 84120.

FIG. 9 *Pullenia quinqueloba* (Reuss), Fossil Bluff; UTGD 84437, x85; (0.35 mm); from UTGD 84010b.

FIG. 10 *Pullenia salisburyi* R.E. and K.C. Stewart, Fossil Bluff; UTGD 84438, x125; (0.25 mm); from UTGD 84010b.

FIGS 11, 12 *Alabamina tenuimarginata* (Chapman, Parr and Collins), Cape Grim; UTGD 84350, x45; (0.6 mm); from UTGD 84006.

FIGS 13-18 *Gyroidina allani* Finlay, Cape Grim; 13 to 15 - UTGD 84364, x90; (0.30 mm); from UTGD 84008. 16 to 18 - UTGD 84365, x55; (0.5 mm); from UTGD 84006.

FIGS 19, 20 *Gyroidina prominula* (Stache), Marrawah; UTGD 84569, x115; (0.27 mm); from UTGD 84561.

FIGS 21-23 *Gyroidina neosoldanii* Brotzen, Marrawah; UTGD 84571, x90; (0.35 mm); from UTGD 84561.

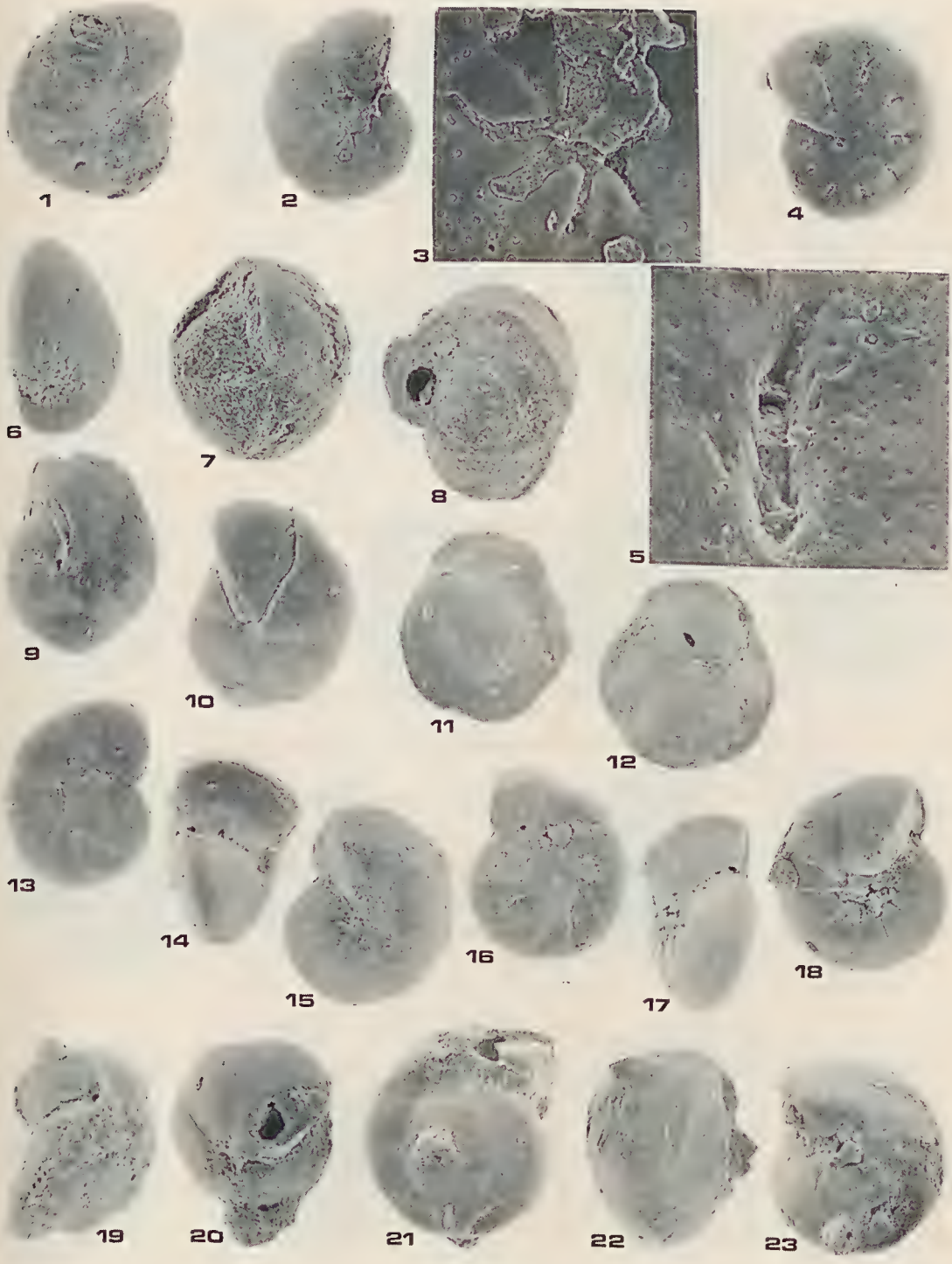

PLATE 5

PLATE 6

FIGS 1-3 *Gyroidina zelandica* Finlay, Marrawah; UTGD 84534, x95; (0.3 mm); from UTGD 84104.

FIGS 4, 5 *Anomalina* (?) cf. *humilis* (Brady), Cape Grim; UTGD 84249, x90; (0.35 mm); from UTGD 84008.

FIGS 6-8 *Anomalina* sp.1, Marrawah; UTGD 84358, x85; (0.35 mm); from UTGD 84113.

FIGS 9, 10 *Anomalinoides macraglabrus* (Finlay), Fossil Bluff; UTGD 84250, x95; (0.3 mm); from UTGD 84010b.

FIGS 11-13 *Anomalinoides nonionoides* (Parr), Cape Grim; UTGD 84251, x70; (0.4 mm); from UTGD 84006.

FIGS 14, 15 *A.* cf. *planulatus* Carter, Redpa; UTGD 84252, x55; (0.5 mm); from UTGD 84095.

FIGS 16, 17 *Anomalinoides subnonionoides* (Finlay), Cape Barren Island; UTGD 84551, x33; (0.9 mm); from UTGD 84554.

FIGS 18, 19 *Anomalinoides* cf. *sphericus* (Finlay), King Island; UTGD 84253, x100; (0.3 mm); from UTGD 84085.

FIGS 20, 21 *Hanzawaia procolligera* (Carter), Fossil Bluff; UTGD 84366, x90; (0.35 mm); from UTGD 84011.

FIGS 22, 23 *Karreria maoria* (Finlay), Marrawah; UTGD 84370, x70, x65 respectively; (0.45 mm); from UTGD 84104.

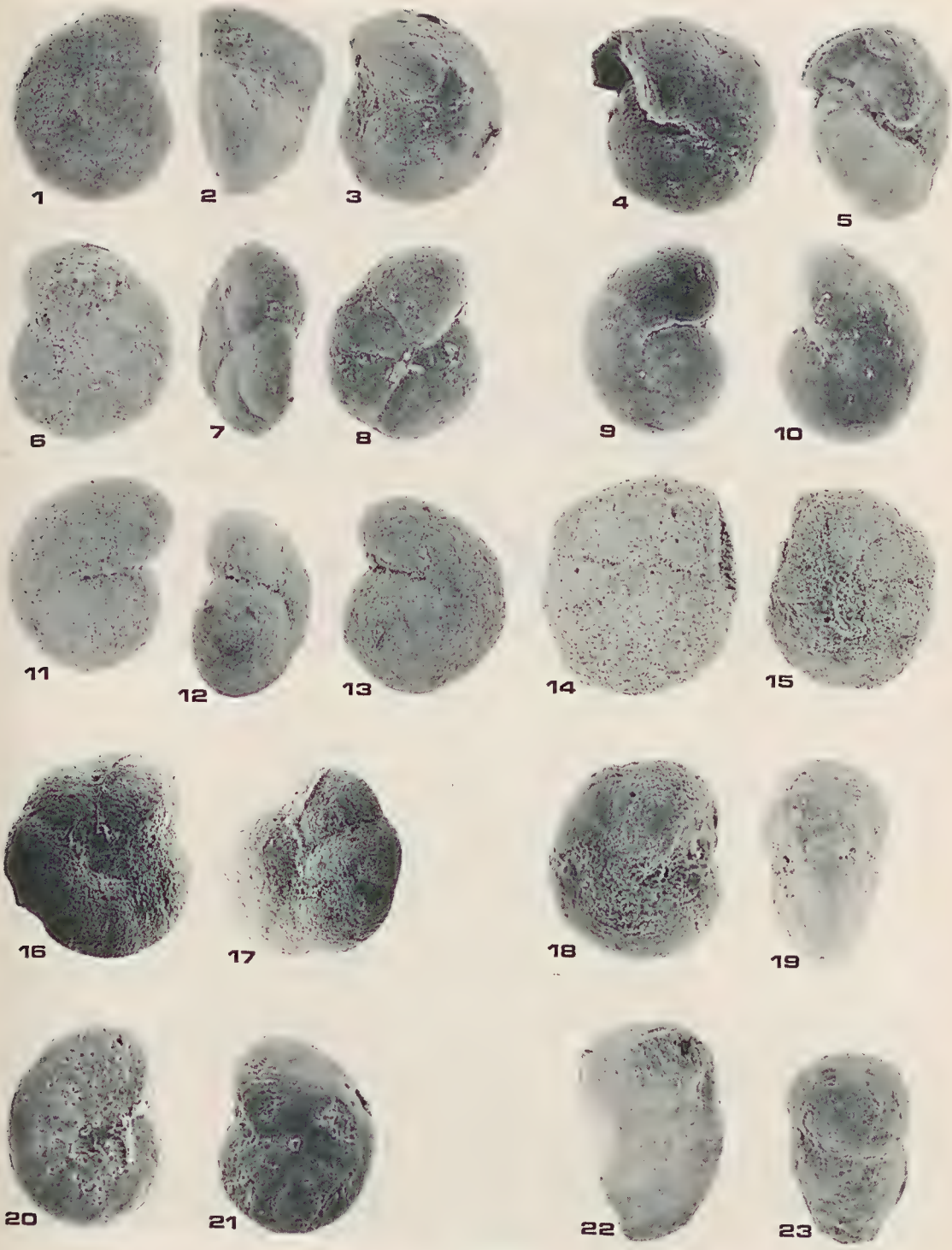

PLATE 6

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FIRES BY THE SEASIDE: HISTORIC VEGETATION CHANGES IN NORTHWESTERN TASMANIA

by Jim Stockton
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(with two tables and three text-figures)

ABSTRACT

STOCKTON, J., 1982 (31 viii): Fires by the seaside: historic vegetation changes in northwestern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 53-66. ISSN 0080-4703. Department of Prehistory, Australian National University, Canberra, A.C.T.

Dramatic changes in landscape and vegetation have occurred on the northern section of the west coast of Tasmania since the invasion by Europeans. Insidious changes such as the introduction of new species are to be expected but the destabilization of large sections of a major landform has also occurred with the development of extensive sand blows. A variety of forms of evidence relating to changes in land use patterns are examined in an attempt to date the start, and assess the extent, of this change.

INTRODUCTION

While searching explorers' diaries and reports for information about the prehistoric inhabitants of northwestern Tasmania I encountered descriptions of vegetation patterns that were often quite different from those observed today. This paper grew as an attempt to synthesize the early vegetation descriptions for the coastal strip of the region. Arbitrary geographical limits are set at the entrance to Macquarie Harbour in the south (145°13'E, 42°13'S), and Big Duck Bay, Hunter Island, to the north (144°43'E, 40°31'S) (see figure 1). The coastal strip discussed is approximately 1 km wide.

BACKGROUND

The west coast of Tasmania is often regarded as a wild landscape; to many visitors it does not appear to have changed greatly since Aboriginal times. Yet as unfriendly as this region seems to our culture, it was the home territory for groups of prehistoric hunters who left evidence of their activities on almost every part of the landscape. The area has seen intense archaeological and ethnographic research in the last 20 years. I propose to look at only two aspects in detail, landforms and vegetation patterns. Historic descriptions of vegetation and landforms along the coast at the period of European contact will be compared to the patterns of vegetation and landforms of the region today.

There are a number of problems in attempting this, some familiar to historians, but others more familiar to botanists, ecologists, and geographers.

Many of the place names in early accounts are no longer used, while other names have moved in the landscape (Stockton 1979; Mackanness 1976, 39) so relocation of what an observer was describing can be extremely difficult. This relocation can sometimes be achieved by map reading, air photo interpretation or by visiting the locality, but some descriptions could not be used as the localities of the given place names are no longer known.

Some travellers gave only the vaguest hints of the route they followed and some even had their major landmarks like mountains and large rivers confused (e.g. see Plomley 1966, 903). Others, particularly surveyors, drew maps to accompany their reports and diaries. Although these can be extremely inaccurate, some maps give boundaries of their

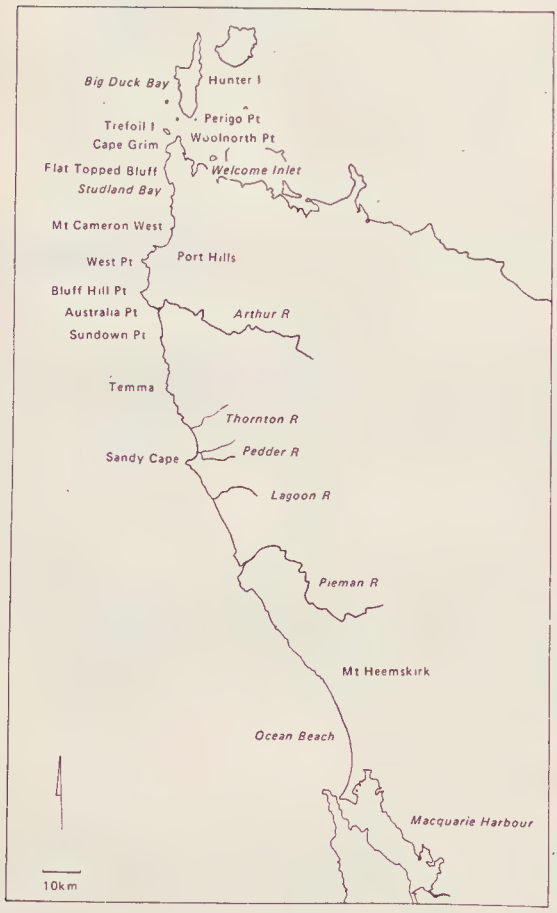

FIG.1 - Map of study area and place names used in text.

observations of vegetation (see figure 2). Appendix 1 sets out the total of 43 observations which can be accurately relocated.

Common plant names have remained stable in the area over the past 150 years and most of the terms of 1820 are still in use today. Scientific names have been a little more fluid as taxonomic studies have progressed.

The final problem is that few of the early explorers were trained observers competent to describe plants, plant communities, soils, landforms and geology. All were recent immigrants to the colony to whom Tasmania was bizarre and alien. Hardwicke (1861) was a ship's captain who carried out a reconnaissance from the sea about 1824. C.P. Lorymer (1861), Joseph Fossey (1861), Alexander Goldie (1861) and Henry Hellyer (1861) were surveyors and agriculturalists working for the Van Diemen's Land Company, a large agricultural firm granted land in northwestern Tasmania, but managed from England. These reports cover surveys carried out in the 1820's. Original maps from these surveys have survived, which together with their reports provide excellent geographical records. John Helder Wedge (1861, 1962) was a government surveyor sent to inspect the land available for selection by the Van Diemen's Land Company. George Augustus Robinson, by trade a builder, was appointed Conciliator to the Tasmanian Aborigines. All these men showed courage and endurance in travelling through the unknown landscape of Tasmania of the early 1800's. That they managed to record their field observations so well was a feat of intellectual endurance.

VEGETATION COMMUNITIES AND LANDFORMS

The early explorers used four broad categories to describe the vegetation patterns they encountered: heath, tea-tree swamp, forest and grassland. In the following sections the patterns of relationships between vegetation communities and landforms will be examined. Evidence for changes in these patterns will be presented for each community.

Heath communities

In the historical record large areas of heath are described. *Banksia marginata* is the most commonly noted species. The descriptions probably include sedgeland heath in this community, though it is rarely explicitly stated. There are few references to scrub communities. Either the explorers did not encounter dense scrub on the coast, or they failed to record it. Heath species would develop a scrub structure if the shrubs are

allowed to grow more than two metres tall. On the coast plant height is regulated by nutrition, waterlogging, buffeting by wind, salt spray and fire frequency. Nutrition, waterlogging, wind and salt spray factors can be taken as constant over time, so the variable to examine is fire frequency.

In the Lands Department cattle agistment runs extending from West Point to the Pieman River the preferred fire frequency interval is about 3-5 years (J. Hanson pers. comm.). This ideal is only obtained in areas of easy access such as along roads and tracks. Extensive areas of less accessible heath community have moved towards a closed scrub. References to Aboriginal burning are abundant and I shall return to this point later.

Tea-tree swamp communities

Sheltered waterlogged locations are described by the explorers as supporting tea-tree communities. These are easily recognizable as the *Melaleuca* spp. and *Leptospermum* spp. dominated communities which develop into a very dense forest of low trees in sheltered swamp localities. The blackwood, *Acacia melanoxylon*, which is cut for milling, grows in the larger swamps. East of the coastal strip, some large areas of tea-tree swamp have been altered by draining and clearing for farmland, e.g. Togari, but the swamps near the coast are not large enough to warrant this sort of activity.

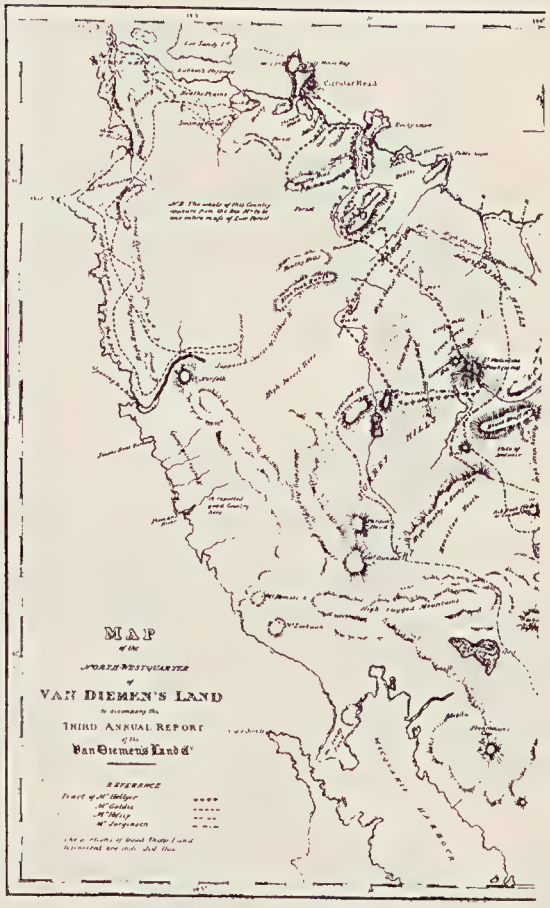

FIG. 2 - Map to accompany the Third Annual Report of the Van Diemen's Land Company (VDL/343/5).

Forest communities

There were no rainforests along the coastal strip, although large areas inland were dominated by a *Nothofagus cunninghamii* community. Patches of eucalypt forest did occur on areas of better soil such as the basalt soils of Mount Cameron West and the Port Hills. The vegetation structure appears to have been tending towards an open woodland.

Today the Port Hills are largely cleared for pasture, but stumps of large *Eucalyptus* trees remain. The southern and eastern lower slopes of Mount Cameron West are now an open woodland of *E. viminalis-E. ovata* over a *Poa* grassland and *Lomandra longifolia* tussock understorey (Brown 1980, 26). This area probably looks much as it did when the first settlers arrived, but other parts of the mountain are under pasture.

Grassland communities

The early explorers were looking for areas suitable for English sheep and cattle, so perhaps these communities were "over recorded" in their diaries and reports while too little mention was made of less economically valuable communities. Fortunately, maps of areas suitable for sheep were made by Van Diemen's Land Company surveyors and the diaries

FIG. 3 - Figure 2 redrawn on a modern base map.

and reports can be cross-checked against these. The level of agreement is surprisingly high. Figure 2 is an example of one of these maps. Figure 3 is an attempt to redraw this on a modern base map. The scenario conveyed by the early accounts is of large tracts of grassland with scattered trees and shrubs on southwestern Hunter Island, Woolnorth Point to Studland Bay, Mount Cameron West, and a discontinuous coastal strip from Mount Cameron West to about 10 km south of the Pieman River. The descriptions repeatedly mention grassy hills, park-like appearances and suitability as sheep runs. The scattered trees noted in this community are *Banksia marginata*, *Melaleuca* spp., and dwarf gum - probably mallee form *E. nitida*. The only grass species named is "kangaroo grass" (Goldie 1861, 6; Plomley 1966, 619). J.D. Hooker in the *Flora of Tasmania* described *Anthistiria australis* R. Br. as having the "Colonial name - Kangaroo Grass" (1860, 107). The name has since been changed to *Themeda australis* and it is still called "kangaroo grass" (M. Cameron pers. comm.). However M. Brown (pers. comm.) suggests the habitats Robinson described do not sound right for *Themeda* but seem more appropriate for *Poa poiformis* or possibly *Poa labillardieri*. *Themeda* occurs on calcarenite ridges and swales but avoids siliceous sands or recent dunes. The *Poa* spp. are rarely found more than 500 m from the sea (G. Hope pers. comm.).

The attempts to run sheep on these grasslands were short lived, lasting less than five years. Soil deficiencies, particularly of cobalt and copper (Colin Bastock pers. comm.) produced a condition called "coastiness" and many animals died. By 1834 the sheep had been removed from West Point and Studland Bay (Plomley 1966, 844). Later cattle, which are more resistant to these deficiencies were tried, usually on a short-term basis such as while being driven to market at the mining towns further south. Today most of the region is used only for winter agistment of cattle, a form of regulated free range grazing.

These prehistoric grasslands grew on two soil types - basaltic soils at Cape Grim and the Port Hills and sandy soils on Quaternary sandsheets on Hunter Island, at Studland Bay, north of Mount Cameron West, and on the discontinuous strip south of the mountain to the Pieman River. The basaltic soil areas have mostly been cultivated and sown to pasture (see Appendix 1, references 4, 7, 8, 9, 10, 15, 18, 19, 21, 23). The sandsheet grasslands have changed in other ways.

The sandsheets on which the grassland community grew have been drastically altered in most areas. Deflation of the sand dunes by wind is one of the outstanding features of the west coast today. The development of the sand blows is poorly documented and I have not yet been able to determine when the process started, only that sand blows are not mentioned by any of the explorers. Legge (1929, 323-324) cited second-hand descriptions of the process starting after 1880.

> "Pioneer settlers of this coast, such as those of Marrawah, for instance, can remember, when, some 45 years ago, they first took up land out there, these great sand-dunes being covered with dense coastal scrub right down close to the edge of the wild beaches, but since the introduction of stock, and on account of the periodical burnings by the graziers for improvement of the rough pastures, the surface of the light soil has been broken, and tracks and pathways have been made, allowing the wind to make inroads upon the sandy soil, laying bare the roots of plants and trees, carrying on its work of denudation, leaving today many areas of absolute desert land."

The process is continuing today in spite of some 50 years of marram grass planting programs in the area (D. Steane pers. comm.).

Of the areas formerly described as grassland communities on stable sand dune landforms less than 60% remain. It was difficult to estimate the area of these landscape units without lengthy calculations. Fortunately, the coastal mapping operation of the CSIRO Division of Land Use Research, provided a way of estimating the total Holocene sand area, and the area of bare Holocene sand (Galloway *et al.* 1980). The system of measurement used by the CSIRO is based on point samples spaced so as to give one sample per 3 km^2 (Galloway *et al.* 1980, 7). The results of this method of sampling for the coastal strip from Woolnorth Point to Macquarie Harbour gives estimates of 165 km^2 of Holocene sand of which 66 km^2 or 40% is bare of vegetation. As restabilized areas of marram grass are not included in the bare sand unit, the area of Holocene sand which has been unstable in the recent past is even greater. The largest grassland remnants are at Temma, Australia Point, Arthur River mouth, and southwestern Hunter Island. Of these, Hunter Island conforms most closely to a structure commonly described in 1820-1840, i.e. of a grassland with scattered emergent low trees of *Banksia marginata* and *Eucalyptus* spp. - almost a "savannah" pattern.

Relict dune landforms with grassland seem to have survived where the foreshore contains extensive rock platforms, e.g. Greens Creek, north of Temma, north of Lagoon River or where the beach line is aggrading, e.g. the southern half of Ocean Beach. These situations lessen the probability of the front dune being undercut by wind or wave removal of sand. Kirkpatrick (1977b, 70) described small areas of natural grassland on a narrow coastal strip, and in a few swales in the Holocene sand dune complex at Ocean Beach. The coastal strip north of Trial Harbour is dominated by *Poa poiformis* tussock grass.

In the summers of 1979/80 and 1980/81 samples of the most common grasses of the remnant grassland community in the vicinity of West Point were collected. About half the species of this area of marginal land with minimal management proved to be exotic (table 1). Management today consists solely of firing the vegetation to produce new growth, or "green pick" in local vernacular. In the past there may have been more intense management. There is a folk tradition that farmers would travel along the coast on horseback and flick lighted matches into the vegetation to start fires. On the return journey they would carry a bag of mixed grass seeds on the front of the saddle and scatter seed over the burnt ground. One of the grasses in the mixture was likely to find conditions suitable for growth. Introduced grass species would also be carried into the area in the gut contents of horses and cattle. Many of the species in the list are no longer regarded as pasture grasses, but were introduced for that purpose. Some have very short growing seasons, and could not compete in modern pastures. The presence of clovers adds an interesting complication. These nitrogen-fixing legumes increase soil fertility, thus facilitating invasion of new species not adapted to the very poor native soils.

TABLE 1

MOST COMMON SPECIES FOR REMNANT GRASSLAND AREA AT WEST POINT.

	Indigenous	Exotic		Indigenous	Exotic
Agrostis stolonifera		x	*Lythrum hyssopifolium*		x
Asperula conferta	x		*Medicago lubulina*		x
Bromus diandrus		x	*Melilotus indica*		x
Cakile edentula	x		*Parentucellia viscosa*		x
Dactylis glomerata		x	*Plantago coronobus*		x
Danthonia sp.A		x	*Plantago lanceolata*		x
Danthonia sp.B		x	*Poa pratensis*		x
Dichondra repens	x		*Poa rodwayi*	x	
Epilobium hirtigerum	x		*Scirpus nodosus*	x	
Holcus lanatus		x	*Senecio hispidulus*	x	
Juncus articulatus	x		*Stipa stipoides*	x	
Lepidosperma gladiatum	x		*Tetragonia implexicoma*	x	
Lotus australis	x		*Trifolium repens*		x

IMPACT OF VEGETATION CHANGE ON STABILITY OF SANDSHEET LANDFORMS

In describing the coastal landforms of Tasmania Davies noted two forms of dunes. One of these is a "transgressive dune originating from wind erosion of a pre-existing stabilized dune" (1965, 22). Davies suggested that there is evidence from many coastal areas that the present cycle of transgressive dune development began in the nineteenth century as a result of burning and stocking of dune country previously stabilized by vegetation.

The mechanics of the formation of unconsolidated dunes were described by Macphail *et al.* (1975, 59).

> "This process starts usually with fire damage to the vegetation on the front of the foredune, or from damage by vehicles or cattle to the base of the dunes. Removal of sand undercuts the vegetation higher up the dune, with consequent slumping and removal of the unconsolidated sand by wind funneling. Sand moved from the dune front is deposited on the lee of the front dune, burying the heath and scrub. Eventually a break in the front is established and the wind funneling through the gap moves the sand landwards, covering extensive areas of dune and bench."

Causes of dune destabilization are often commented on in other botanical studies in the region. Brown (1980, 29) suggested mechanical damage through over-grazing and too-frequent use of fire to provide "green pick". Macphail *et al.* (1975: 32, 48, 59) stated that wind erosion has been initiated by fire, vehicles, and grazing. Cattle are certainly a new factor, but fire has been used by man to alter the coastal vegetation for millenia (Jones 1969). The questions are: What was the prehistoric fire pattern like? Why did the Aborigines burn the vegetation? What were the patterns of seasonality and frequency? Did these reasons and patterns change with the arrival of Europeans?

ABORIGINAL AND EUROPEAN FIRING PATTERNS

Fires can be started by lightning (Mount 1964). In this discussion it is assumed that this possibility of natural ignition did not change with the arrival of Europeans.

The first recorded indication that Tasmania was occupied was the sighting of bush fires by Abel Tasman in 1642 (Chapman 1980, 40). Later accounts by the early explorers contain numerous references to sightings of fires or smoke. Some descriptions may refer to either Aboriginal camp fires or bush fires. Only rarely is an unequivocal statement

like Baudin's description of the D'Entrecasteaux Channel in 1802 given. "... the mountains ... had been constantly on fire since our arrival". A day later he stated "the entire coast to port was ablaze" (Cornell 1974, 331-332).

The reasons for Aboriginal burning of the bush were varied. Fire was used to drive animals from cover in hunting (Plomley 1966, 840, 629). Another aim of burning was to open up dense vegetation (Plomley 1966, 54, 376). This would be done to make travelling easier (Plomley 1966, 287-288) or to keep tracks open (Plomley 1966, 520). This practice was continued by many explorers and prospectors. There is a hint by Robinson that the Aborigines with him burnt dense underwood to get rid of mosquitoes (Plomley 1966, 840). This is an extremely effective mosquito repellent! Bush fires were used by groups of Aborigines to advertise their position (Plomley 1966, 862-863, 288, 513, 740). Aborigines with Robinson on a hill slightly west of Bothwell were prepared to assert that a yellow tinge in the sky far in the west was the result of the natives of the west coast "burning the woods in those parts" (Plomley 1966, 523).

Lighting fires to mark location was also practised by Europeans (Cornell 1974, 441).

While on a lookout a companion showed Robinson the route of a "native track which was visible from the burnt ground" (Plomley 1966, 905). This pattern of firing along access routes has continued up to the present. It is particularly noticeable on modern air photographs of the study area. Many of the modern roads follow prehistoric routes through the study area, perhaps because they developed along routes of easy foot travel through open (i.e. well burnt) country.

As the Aborigines travelled they would light bushfires which could supply them with fire if the firestick they carried went out (Plomley 1966, 560; Cornell 1974, 307). If their fire did go out they had no means of kindling another (Plomley 1966, 740).

The earliest firestick description I am aware of is from 1789 when Mortimer observed several natives "with pieces of lighted wood in their hands" (Mortimer 1975, 18). There were probably preferred types of wood for firesticks. Use of sheoak, *Casuarina* spp. (probably *C. stricta*), was mentioned by Robinson (Plomley 1966, 385) but casuarinas are not available in many parts of Tasmania, so other types of wood must also have been used. Robinson also noted the use of tea-tree bark (*Melaleuca* spp.) for torches. His use of the term "torches" shows he distinguished them from firesticks. The tea-tree has a layered papery bark which burns very rapidly. It provides a very good light, but is not suitable as a means of transporting fire.

With the arrival of European stock, the practice of firing the country was quickly adopted. It was formally advocated in 1828 by a government surveyor as a means of making land suitable for grazing (Wedge 1861, 1). Robinson noted his uncertainty of the origins of a fire just below the Western Tiers in 1831 (Plomley 1966, 546). In 1834 he noted: "saw the white man's smoke near Port Sorell" from the top of a hill near the Western Tiers (Plomley 1966, 904; 920 note 136).

SEASONALITY

To look at the problem of seasonality of Aboriginal burning I have confined my search to Robinson's journals, and within them to his observations of bushfires or recently burnt ground. Some fires recorded may have been started by lightning, but this factor cannot be evaluated.

There are not enough records from the northwestern corner of Tasmania, so I have listed his observations throughout Tasmania. The occurrence of fires by month of year and region is shown in table 2. Even though a total of 19 observations is small, there is a surprising agreement between the pattern for the northwestern coast and the remainder of the island. The overall pattern can be interpreted in several ways. Firstly, burning occurred at all seasons of the year. This is an important point, lightning fires would

TABLE 2

ROBINSON'S OBSERVATIONS OF BUSH FIRES AND RECENTLY BURNT AREAS.

	Northern part of west coast	Other parts of Tasmania	Total
January		839,840	2
February	849	842,842	3
March	858,862	136	3
April			
May			
June	172,184		2
July	760	188,375,898	4
August			
September			
October	673	249,260	3
November		285	1
December		560	1
			19

Page numbers refer to Plomley (1966).

have mostly occurred in summer. Secondly, the summer season of December through to March accounts for 9 out of 19 observations, suggesting three possible interpretations. One, firing was more common in summer. Two, summer fires burnt for longer. Three, summer fires covered larger areas than winter fires and so were more visible. Also, Robinson preferred to carry out field operations in summer, which leads to an imbalance in the seasonality of his records. One longtime resident of the west coast, Mr R. Wainwright, has described the burning patterns followed in the 1920's and 1930's on Woolnorth, the Van Diemen's Land Company property at the northern end of the study area (pers. comm.). Management here was typical of the northwestern region from the 1830's to about 1950. All the country was kept well burnt. The higher plains country was fired in September as soon as it was dry enough. The lower country and swamps were fired in summer, but while the peat was still too wet to burn. If the grazing land was not burnt regularly it would change from grassland to scrub. The transition of grazing land to scrub has since occurred at Welcome Marsh and several other areas as regular firing was not continued after about 1950. Mr Wainwright also commented on two important prehistoric food species which were snared for skins and meat by settlers, the brush possum, *Trichosurus vulpecula* and the red-bellied pademelon, *Thylogale billardierii*. In his days as a snarer, they would burn eucalypt forest to encourage regrowth on which the possums feed. Unburnt forest had very few possums. Similarly, snarers got few wallabies in unburnt areas, and these animals were usually in poor condition. So burning improved the living conditions of both possums and wallabies.

Fire ecology in Tasmania is a young field study and still an area of sometimes emotional contention. To date attention has focussed on forest succession (Jackson 1968; Mount 1964, 1979), with only passing reference to coastal heaths (Jackson 1965, 30). Kirkpatrick's review of heath communities (1977a) deals only with Hunter Island in the study area. Judging from the evidence reviewed, there were no detectable major changes in fire frequency in the transition from Aboriginal to European occupation of the west coast (Kirkpatrick 1977b). Although the ultimate aims of the two cultures were irreconcilable, the means they used to manage the vegetation were similar. The arrival of cattle on the landscape is the factor which coincides with the destabilization of the grassland community on sandhills. Historical evidence in the study area suggests that the effect of cattle grazing on the sandsheet landforms does not necessarily lead to the development of sand blows, but in the majority of locations this has occurred.

Today, there is a new vegetation type which dominates a large proportion of the coast - the marram grass community. Marram grass, *Ammophilla arenaria*, is a species which colonizes and binds free sand much more rapidly than native grasses. It was introduced to Australia by Baron von Mueller, and was being used in northwestern Tasmania at Stanley to stabilize mobile dunes by 1895 (Ashworth and le Soeuf 1895, 136). Being a specialized colonizing plant, it cannot compete with established vegetation, but the destabilization of the coastal sandsheets and deliberate planting programs account for its widespread distribution. In the vegetation of the 1820's and 1830's it would probably not have been able to gain a place.

CONCLUSIONS

Of the vegetation communities found on the west coast during the exploration period of 1820 to 1840 the one which has persisted most successfully is the heath community. The small swamps of the coastal fringe have also remained. The bulk of the woodland community on the basaltic soil areas has been cleared and sown to pasture, and the woodland community is now seen only as remnants. The grassland community on stable sand dune landforms has changed in two ways. Firstly, the remnant stable dunes in the area now contain many introduced species. Secondly, a large proportion of this landform has destabilized into mobile sandsheets. On these unstable sandsheets a new community has developed, the marram tussock grass community.

The date of the initial development of the sand blows is uncertain, but none of the explorers record observations of unvegetated sand dunes, although it seems probable that some existed.

By 1894 there were sandblows at Stanley on the north coast (Ashworth and le Soeuf 1895, 136). By 1934 sand blows at Sandy Cape had extended 3.2 km inland (Circular Head Chronicle 31.1.34, 1). The probable date of the start of the process is between 1848 and 1890.

From evidence reviewed on Aboriginal and European use of fire, there is no definite indication of a change in frequency or seasonality pattern. The introduction of European stock is the factor which coincided with the start of widespread sand dune mobilization.

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APPENDIX 1

HISTORIC AND MODERN VEGETATION PATTERNS.

1. Big Duck Bay to Perigo Point, Hunter Island.
   Past veg: low grassy sandhills with clumps of honeysuckle trees - good feed for sheep (1832)
   Present veg: pasture grasses with scattered *Eucalyptus* sp. and *Banksia marginata* trees
   Obs. & ref: Robinson (Plomley 1966,657).

2. Trefoil Island.
   Past veg: beautiful pasture (1830)
   Present veg: *Poa* tussock grassland
   Obs. & ref: Robinson (Plomley 1966,175).

3. Woolnorth Point.
   Past veg: a rich grass pasture on the coast, with heath inland (c. 1824)
   Present veg: introduced pasture species
   Obs. & ref: Hardwicke (1861,2).

4. Woolnorth Point to Studland Bay.
   Past veg: good sheep land (c. 1828)
   Present veg: introduced pasture species
   Obs. & ref: VDL/343/5.

5. Cape Grim to Arthur River.
   Past veg: nearly all the country is grassy sandhills, and excellent sheep walks (1832)
   Present veg: too varied to describe, see references 7 to 32.
   Obs. & ref: Robinson (Plomley 1966,616).

6. Cape Grim to Mount Cameron West - coastal strip.
   Past veg: abundance of feed for sheep (1828)
   Present veg: as for 5
   Obs. & ref: Wedge (1861,3).

7. Cape Grim and vicinity.
   Past veg: good sheep land with the exception of a low plain which is suitable for cattle (1826)
   Present veg: cultivated areas of pasture grasses and areas of closed shrubs of *Melaleuca ericifolia*. *Poa* tussock grassland on hillslopes
   Obs. & ref: Goldie (1861,6).

8. Cape Grim.
   Past veg: luxuriant grass, fine country for sheep (1828)
   Present veg: as for 7
   Obs. & ref: Wedge (1861,3).

9. Cape Grim (?).
   Past veg: grassy hills (1830)
   Present veg: as for 7
   Obs. & ref: Robinson (Plomley 1966,175).

10. Flat Topped Bluff.
    Past veg: grass and stunted tea-tree (1830)
    Present veg: as for 7
    Obs. & ref: Robinson (Plomley 1966,174).

11. SW of Welcome Inlet.
    Past veg: extensive forest of tea-tree and light and blackwood (1834)
    Present veg: low forest of very dense low trees dominated by *M. ericifolia* with scattered *Acacia melanoxylon*
    Obs. & ref: Robinson (Plomley 1966,865).

12. W of Welcome Inlet.
    Past veg: tea-tree and heathy swamp land (1832)
    Present veg: mainly an open heath and sedgeland comprising *M. squarrosa*, *M. ericifolia* and *Leptospermum scoparium*
    Obs. & ref: Robinson (Plomley 1966,656).

13. Studland Bay.
    Past veg: good sheep land (1826)
    Present veg: bare mobile sand blows
    Obs. & ref: Goldie (1861,6).

14. Inland from Studland Bay.
    Past veg: good sheep pasture (1832)
    Present veg: as for 13
    Obs. & ref: Robinson (Plomley 1966,656).

15. Mount Cameron West.
    Past veg: covered with grass and large gum and peppermint trees, an open forest of clear walking (1830)
    Present veg: tussock grassland with areas of very dense *M. ericifolia* scrub. On the southern slopes is *Eucalyptus* woodland with a heath understorey
    Obs. & ref: Robinson (Plomley 1966,174).

16. View from Mount Cameron West.
    Past veg: broad extensive plains covered with grass and small grassy hills, and small belts of open forest interspersed throughout (1830)
    Present veg: sand blows and restabilized areas with marram grass.
    Obs. & ref: Robinson (Plomley 1966,174).

17. Mount Cameron West vicinity (?N side).
    Past veg: heath and swamp (1826)
    Present veg: as for 16
    Obs. & ref: Goldie (1861,6).

18. Mount Cameron West
    Past veg: very good feed (1826)
    Present veg: pasture grasses on flat areas, and tussock grassland with areas of very dense *M. ericifolia* scrub on slopes.
    Obs. & ref: Goldie (1861,6).

19. Mount Cameron West and the adjacent coastal strip.
    Past veg: luxuriant pasturage (1828)
    Present veg: as for 18
    Obs. & ref: Wedge (1961,3).

20. N, E and S of Mount Cameron West.
    Past veg: good sheep land (c.1828)
    Present veg: restabilized sand blows with marram grass along the coastal fringe, with heath or *Eucalyptus* woodland with a heath understorey in inland areas
    Obs. & ref: VDL/343/5.

21. Mount Cameron West to West Point.
    Past veg: narrow coastal strip of good land with forest inland (1828)
    Present veg: the coastal strip is now a complex pattern of marram grass restabilized dunes. pasture covered relict dunes, and coastal heath on areas of quartzite bedrock. The forest areas are now cleared and sown to pasture.
    Obs. & ref: Wedge (1861,3).

22. Port Hills.
    Past veg: same as Mount Cameron West - very good feed (1826)
    Present veg: introduced pasture species
    Obs. & ref: Goldie (1861,6).

23. West Point c. 3 km inland.
    Past veg: wet heathy plains and tea tree knee deep in water (1826)
    Present veg: heath dominated by *L. scoparium-M. squarrosa* association and swamps with *M. ericifolia*
    Obs. & ref: Goldie (1861,6).

24. West Point.
    Past veg: small quantities of land adapted for sheep (1828)
    Present veg: grassland on the coastal fringe, with heath inland
    Obs. & ref: Wedge (1861,3).

25. West Point.
    Past veg: an extensive heathy plain (1832)
    Present veg: as for 24
    Obs. & ref: Robinson (Plomley 1966,653).

26. West Point (? S of the point).
Past veg: miles of grassy sandhills ... an excellent sheep walk (1832)
Present veg: sand blows restabilized with marram grass
Obs. & ref: Robinson (Plomley 1966,616).

27. West Point to Bluff Hill Point.
Past veg: grassy hills covered with honeysuckle trees (1830)
Present veg: at West Point and Bluff Hill Point there are remnant stable dune landforms with vegetation similar to the reference. Elsewhere the coastal strip is sand blows restabilized with marram.
Obs. & ref: Robinson (Plomley 1966,172).

28. Coastal strip 1.5 km wide from 8 km S of West Point to the Arthur River.
Past veg: good sheep land (c. 1828)
Present veg: marram grass on restabilized dunes with coastal heath inland
Obs. & ref: VDL/343/5.

29. C. 8 km S of West Point.
Past veg: a rich grass pasture on the coast with heath inland (c. 1824)
Present veg: as for 28.
Obs. & ref: Hardwicke (1861,2).

30. Australia Point to Temma.
Past veg: grassy hills with dwarf gum and honeysuckle trees (1828)
Present veg: recently mobile sand blows near the coast have been stabilized with marram grass. Inland dunes which have remained intact are covered with *Lomandra longifolia* tussock grassland, introduced pasture grasses and clumps of *Leptospermum laevigatum* and *A. sophorae*.
Obs. & ref: Wedge (1861,3).

31. Arthur River mouth.
Past veg: the banks are high and hilly and covered with grass (1830)
Present veg: as for 30
Obs. & ref: Robinson (Plomley 1966,171-2).

32. Arthur River, 1-2 km inland.
Past veg: heath with clumps of scattered gum trees (1834)
Present veg: as described in reference
Obs. & ref: Robinson (Plomley 1966,849).

33. Coastal strip 1.5 km wide from 3 km S of the Arthur River to 11 km S of the Pieman River.
Past veg: good sheep land (c. 1828)
Present veg: this strip is mostly unvegetated mobile sand blows and marram restabilized dunes. Inland of the sandsheets is coastal heath on quartzite bedrock
Obs. & ref: VDL/343/5.

34. Sundown Point to Sandy Cape.
Past veg: honeysuckle and other trees and copses are interspersed over the country with clear heathy plains and hills ... good sheep walks (1833)
Present veg: remnant dune areas have pasture grasses with scattered trees and shrubs, but most dune areas have become unstable sand blows. Some of the sand blows have been restabilized by marram grass. Non-dune landforms on the quartzite bedrock have coastal heath.
Obs. & ref: Robinson (Plomley 1966,790).

35. 2 km N of Temma to Thornton River.
Past veg: the whole extent of the country is clear of wood, with undulating grassy patches and heathy hills, and has the appearance of a park (1830)
Present veg: as for 34
Obs. & ref: Robinson (Plomley 1966,170).

36. Pedder River, c. 2 km inland.
Past veg: good grassy meadows, each one enclosed with honeysuckle and tea-tree (1830)
Present veg: areas of tussock grass and other herbs, with clumps of shrubs, mostly *Leptospermum laevigatum* and *Acacia sophorae*. *Melaleuca ericifolia* dominates the damp area.
Obs. & ref: Robinson (Plomley 1966,168).

37. Sandy Cape.
Past veg: plains and small grassy hills (1830)
Present veg: mobile unvegetated sand blows and marram grass restabilized dunes.
Obs. & ref: Robinson (Plomley 1966,168).

38. 16 km S of Sandy Cape to (?) Sandy Cape.
Past veg: a fine belt of grassy hills commencing 16 km S of Sandy Cape, well adapted for a sheep walk (1833)
Present veg: huge unvegetated mobile sand dunes are the dominant landform. Behind some areas of rocky headland are remnants of stable dune landforms vegetated by grassland and coastal heath.
Obs. & ref: Robinson (Plomley 1966,789).

39. N of Lagoon River
Past veg: resembles in appearance of park with extensive grassy hills with honeysuckle trees (1830)
Present veg: mobile unvegetated sand blows and stable dune areas with vegetation of grassland with scattered shrubs of *Banksia marginata* and *Leucopogon parviflorus*.
Obs. & ref: Robinson (Plomley 1966,166).

40. S of Lagoon River.
Past veg: extensive plains with grassy hills (1830)
Present veg: mobile sand blows
Obs. & ref: Robinson (Plomley 1966,166).

41. W foothills of North Heemskirk Spur, Mount Heemskirk and Cumberland Hill.
Past veg: the land covered with heath and fine shrubs for several miles ... the land covered with heath and a few shrubs (1830) moor and heathy land (1833)
Present veg: mixed heath and sedgeland communities, of which the principal species are *Leptospermum nitidum*, *Epacris lanuginosa*, *Banksia marginata* and *Leptospermum scoparium*.
Obs. & ref: Robinson (Plomley 1966,760).

42. Ocean Beach.
Past veg: a sandy beach 800 m in width in the rear of which are sandy hills (1830)
Present veg: about half this strip is mobile sand blows. The remainder is stable sand dune landforms with an open scrub. Principal species are *A. mucronata*, *A. sophorae* and *Leptospermum scoparium*.
Obs. & ref: Robinson (Plomley 1966,160).

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PALAEOENVIRONMENT OF THE DARLINGTON LIMESTONE (EARLY PERMIAN), TASMANIA

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with three text-figures, two tables and one plate

ABSTRACT

BRILL, K.G., 1982 (31 viii): Palaeoenvironment of the Darlington Limestone (Early Permian), Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 67-84. ISSN 0080-4703. St Louis University, St Louis, Missouri, U.S.A.

The Early Permian Darlington Limestone in the Tasmania Basin consists of fossiliferous mudstone, siltstone and impure limestone. It was deposited in a somewhat restricted basin with uplands on the northeast and east, the northwest, and probably the southwest. Icebergs from glaciers on the uplands or sea-ice may have transported erratic lonestones into the basin. Cold, low salinity water is indicated by a foramol fauna which contained many individuals but relatively few genera and which is rich in foraminifera, bryozoans, spiriferids, and pelecypods.

Hydraulic energy was generally low. Little sorting and few sedimentary structures were observed. Evidence of current action is mainly on the periphery of the basin and suggests currents from the southwest. Such evidence is mostly the orientation of fossils. Islands such as the Beaconsfield-Frankford island, and shallows probably impeded current action in the basin.

INTRODUCTION

The Darlington Limestone ("Eurydesma" Limestone of authors) was named by Banks (1957) for exposures at Fossil Cliffs, north of Darlington on Maria Island. It was assigned to the lower unit of the Golden Valley Group (Wells 1957). The Golden Valley Groups is a unit of the Parmeener Super-Group (Banks 1973).

The Darlington Limestone is a facies of the Golden Valley Group in southern Tasmania and of the upper part of the Masseys Creek Group in northern Tasmania. Exposures of the formation are scattered over much of the State except for the northeast, northwest and southwest (Banks 1962, fig.30d). Its thickest and best development is at Fossil Cliffs on Maria Island. To the west and north of this locality it consists of thin beds or lenses of impure limestone in a thicker sequence of clastic strata.

The limestone is unusual in that it contains numerous randomly scattered clastic fragments, the most notable being pebbles and boulders of crystalline and sedimentary rocks, herein referred to as lonestones. Except in a few places, the lonestones seem not to be confined to particular bands. Many of these are presumed to be rafted fragments, dropped from icebergs or pack ice. Sand and silt-size terrigenous debris was probably derived from floating ice but some of the finest debris may be of aeolian origin.

Summary faunal lists are given in Banks (1962) and in Clarke and Banks (1975). The principal elements of the fauna are bryozoans, molluscs and spiriferids. The diversity of the fauna is not great but the number of individuals of a particular species is commonly large (Clarke and Banks 1975). Based on faunal zonation in eastern Australia this fauna has been assigned to the Middle Tamarian faunizone 2 (Clarke and Farmer 1976). Although this faunizone is associated with the limestone, it also embraces clastic strata, which northwest, west and southwest of Maria Island, both underlie and overlie the limestone.

Palaeoenvironment of the Darlington Limestone, Tasmania

This study was undertaken by the writer during the latter part of 1978 while a visitor at the Geology Department of the University of Tasmania. The writer is most grateful to Professor D.H. Green for generously providing use of the facilities of the Geology Department and funds for laboratory work. The writer is deeply indebted to Dr Maxwell R. Banks of the Geology Department for suggesting the problem and for his many kindnesses, as well as for his help and encouragement as the work progressed. Thanks are due also to Mr M.J. Clarke of the Geological Survey of Tasmania for his assistance and valuable discussions in the field on Maria Island. The responsibility, however, for opinions expressed in this paper belongs to the writer alone. Dr Alastair McKee of the University of Tasmania made the SEM photomicrographs, and Wendy Spencer prepared the insoluble residues. Landowners and many others aided the writer in many ways. To all he is grateful.

STRATIGRAPHY

Maria Island

The type section of the Darlington Limestone (Banks 1957) is located at the north end of Maria Island. Here the formation is about 16 m thick and overlies the conglomeratic Erratic Zone. The writer measured two detailed stratigraphic sections about 300 m apart at opposite ends of the Fossil Cliffs exposure. The eastern section, herein called the East Fossil Cliffs (EFC) differs somewhat from the western section called the West Darlington (WD). The latter contains more lonestones.

During deposition of the Darlington Limestone the shore lay on the east side of Maria Island, about 5 km east of the present Fossil Cliffs (Banks 1962). The underlying Middle Palaeozoic Mathinna sandstone and quartzite and Devonian granite seems to have provided many of the detrital fragments which are present in the Darlington Limestone. Lonestones of yellow siltstone and fine-grained quartzitic sandstone are present in the upper parts of both sections. These fragments appear to have been derived from the Mathinna Formation. Granite fragments are also present, but seem to be fewer in number than might be expected so close to the source. However, boulders of granite (and phyllite) 0.33 m in long dimension occur in the lower metre of the Fossil Cliffs section. Lonestones are of various types of metamorphic rocks. One boulder of schist is 0.5 x 0.5 x 0.4 m (Banks 1962). The exact source of many of these metamorphic rocks has not been determined but many of them may have originated in western Tasmania (Banks 1962).

As may be seen in figure 2, the distribution of lonestones is not uniform laterally between the two sections, nor is there a consistent vertical pattern. This further suggests that the lonestones are erratics.

In the section of the Darlington Limestone at Fossil Cliffs, Banks (1957) recognized 11 cycles which consist of "an alternation of *Eurydesma* calcirudite and bryozoal siltstone near the base, and *Eurydesma* calcirudite and spiriferid calcirudite higher up". He suggested that the spiriferid calcirudite member of the cycle replaces the bryozoal siltstone member towards the top and attributed (1962) this change in sedimentation to a shallowing of the sea.

In the bryozoal siltstone, lonestones are rare and where present are small. Fenestrate bryozoans commonly delineate the bedding planes, but in a few places cross the planes at an angle. Small ramose *Stenopora* colonies are common and a few seem to be in growth position, especially near the tops of the beds. The fact that modern ramose bryozoans live in deep quiet water (Wass *et al.* 1970) may indicate a similar environment for the Maria Island siltstone. Some broad platy colonies of *Stenopora johnstoni* also occur.

Eurydesma calcirudites contain not only numerous *Eurydesma* but also *Deltopecten*, spiriferids and *Stenopora*. An unusual phase of this type of calcirudite is coquinite. In each of the two sections there are three beds of coquinite which contain unusually large numbers of valves of *Eurydesma* most of which are disarticulated. More shells and shell fragments than matrix are present and the bedding is generally obscure. The basal

FIG. 1- Isopachous map of limestone in Darlington Limestone.

coquinite (EFC-2 and WD-2 and 3) seems to correlate between sections and EFC 18 correlates with WD-17. The other coquinites appear to be lenticular and do not extend from one section to the other.

Two methods were used on the outcrop to determine the percentage and orientation of fossils and lonestones. On the vertical face the number and orientation were noted on lines parallel to the bedding using the stretched-line method (Johnson 1962). This method was not satisfactory everywhere due to limited exposures and too few identifiable fossils. Where bedding planes were exposed, a quadrat one metre square subdivided into squares 100 mm on the side was laid on the outcrop. The outlines and positions of the fossils and

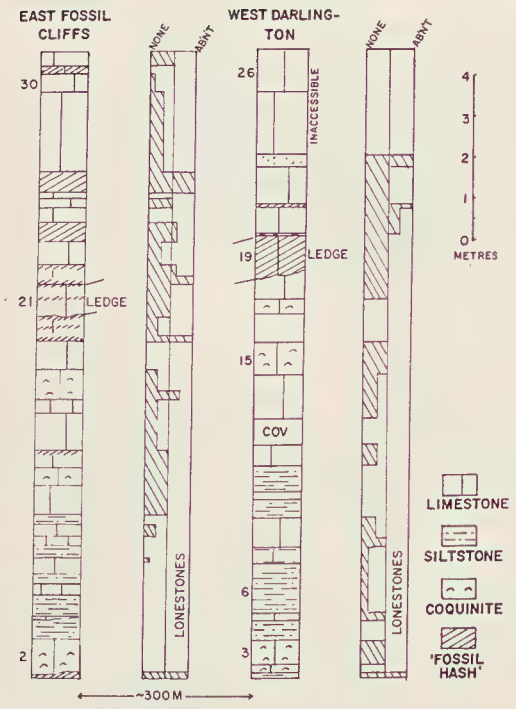


FIG.2- Columnar sections of Darlington Limestone, Fossil Cliffs, Maria Island.

lonestones exposed within the area of the quadrat were drawn to scale on a smaller grid.

Of the basal coquinite (EFC-2) about 50% of the rock is insoluble in hydrochloric acid. The insoluble residue consists of aggregates of fine sugary silica with larger subangular grains of very fine-grained quartz sand. Fragments of monaxon sponge (?) spicules are present. Megascopic shells and shell fragments are mainly convex-side up. Using a stretched-line a count of shells 0.2 m above the base of the bed indicates 64% convex-up; and 0.2 m below the top 50% are convex-up. Some are at odd angles to the horizontal.

The metre quadrat was laid on a bedding plane 0.24 m above the base of Interval EFC-2. About 271 fossils and fragments lay within the area of the quadrat. Of these 61% were *Eurydesma*, 11% spiriferids, 5% *Stenopora*, 2% pectenoids, 18% fossil fragments, and 2% small pebbles of crystalline rocks. Minor amounts of fragments of other bryozoans are present.

This same coquinite is present in the West Darlington section (WD-2 and 3). In WD-2 the stretched-line method indicates that the valves of both *Eurydesma* and pectenoids are 59% convex-up, and that the bed contains 59% *Eurydesma*, 24% pectenoids and 17% spiriferids.

The spiriferid calcarenites contain some disarticulated valves of, and numerous fragments of spiriferids such as *Trigonotreta stokesi* as redefined by Clarke (1979). These beds of calcirudite constitute a "fossil hash" of fragments. A portion of the quadrat was laid on the bedding plane at the top of Interval EFC-22. About 145 fossils and fragments lay within the area of 0.2 square metres. Of these 32% were spiriferids, 17% *Eurydesma*, 7% encrusting bryozoans, 6% pebbles of crystalline rocks, and 33% fossil fragments. On the average the spiriferid calcirudites contain more lonestones than do other types of limestone. Interval EFC-22 contains nine lonestones per 0.2 m^2, and about 22.5% insoluble residue.

In both sections a notable bedding plane lies about 9 m above the base of the Darlington Limestone. The strata above the break contain no *Eurydesma* coquinites, but do have more "fossil hash" and more lonestones than the layers below. The strata above the break may represent sedimentation in shallower and somewhat more agitated water.

Experiments show that single valves of *Eurydesma* tend to orient themselves with the heavy umbo and beak in the direction of the current source. Within the area of the metre quadrat on each of several bedding planes the mean bearing of the umbos of *Eurydesma* was obtained. This was calculated by addition of unit vectors representing each direction in the plane of the bedding. The bearings and probable current directions are shown in Table 1.

These somewhat limited data suggest that some currents moved northerly, and to a lesser extent, southerly parallel to the shore that lay along the eastern side of the present Maria Island. The easterly current may represent a current moving along the

bottom from the coast to the east, or a current moving through a Permian inter-island channel (fig. 1). The significance of these current directions is open to question. In any bottom current the last strong motion of the water tends to orient shells in the direction of that current; thus the orientation of *Eurydesma* may indicate only the final motion of the current rather than the average direction over a long period of time. Banks (1962) postulated that northeasterly longshore currents may have imbricated colonies of *Stenopora* in this area. This observation is compatible with the data herein.

TABLE 1
ORIENTATION OF THE UMBOS OF VALVES OF *EURYDESMA*.
FOSSIL CLIFFS, MARIA ISLAND.

Bed number	Number of specimens	Average bearing	Current from
EFC-2	30 clearly visible	88°	East
EFC-2	24 less clearly visible	95°	East
EFC-22	5 clearly visible	2°	North
EFC-30	28 clearly visible	0.5°	North
WD-16	72 clearly visible	180°	South
WD-16	13 less clearly visible	175°	South

Currents from the west appear to be less common than those from other directions. If the area to the west of the present Maria Island were open water, strong wave action might be expected from the west. If, however, the fetch were impeded by low islands or by ice stranded on shallow barriers, current action from the west might have been greatly reduced. It is postulated that such a barrier existed in Middle Tamarian time trending southward from the area of Mt Connection to the vicinity of Norfolk Bay. It may have coincided with a horst which, in Cainozoic time separated the Midland Graben from the Oyster Bay Graben (Banks 1962, fig.39). If such a barrier were present, it may have consisted of a discontinuous belt of low islands or shallows. Circumstantial evidence for a barrier is found in the paucity of currents from the west at Fossil Cliffs (Table 1), and in the absence of the Bundella Mudstone above the Darlington Limestone in the Maria Island and Cape Surville sections. On the other hand, the presence of lonestones of crystalline rocks derived from western Tasmania (Banks 1962) must be explained. Perhaps these were rafted around the south end of the barrier by southwesterly currents. The shallow water sandstone that overlies the Darlington Limestone at Fossil Cliffs may have accumulated in the restricted trough at the close of deposition of the Darlington Limestone.

Most *Eurydesma* and pectenoid shells are disarticulated and many are broken. Heaped together in coquinites they indicate strong current motion. Although thick shells have been equated with environments where abrasion is great (Stanley 1970), this is not axiomatic. In bed EFC-2 articulated valves of *Eurydesma* stand with the hinge upward and parallel to the average current direction. In their position they resemble the growth position of members of the Unionidae; however, such a position for these *Eurydesma* may be fortuitous.

Disarticulated valves of some *Eurydesma* bear short vertical tubular borings with diameters in two size ranges, namely 0.25 to 0.30 mm and 0.016 to 0.026 mm. Some valves are bored both inside and out; however, no borings appear to penetrate completely through the shell. The organisms that did the boring are not known. The diameters of borings of modern annelids are comparable to those in the larger range (Carriker *et al.* 1969). Borings of blue-green algae are comparable in diameter to those in the smaller range (Budd and Perkins 1980). Borings into the interior surface of the valves indicate that the shells of *Eurydesma* had been disarticulated for some time before burial. If algae were present, a position in the photic zone is indicated.

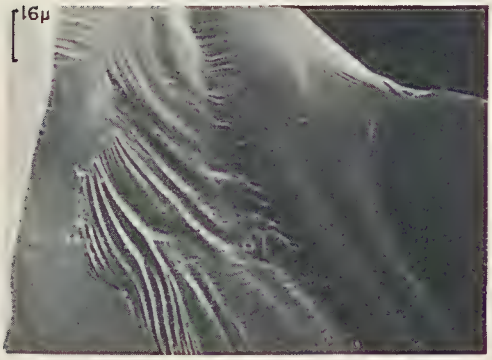
Palaeoenvironment of the Darlington Limestone, Tasmania

The Darlington Limestone is exposed on the east side of South Maria Island. It consists of about 2 m of sandy limestone, some beds of which show cross-stratification. M.J. Clarke (oral communication) states that a shoreline lay a short distance west of this exposure on the present South Maria Island.

Satellite (Woody) Island

A Permian stratigraphic section exposed on Satellite (Woody) Island in D'Entrecasteaux Channel was described by Banks, Hale and Yaxley (1955). Here the Golden Valley Group consists of 1.5 m of Darlington (*Eurydesma*) Limestone overlain by about 12 m of Bundella ("Porters Hill") Mudstone.

The Darlington Limestone is a grey, high silt limestone which lacks sorting. Insoluble residues range from 35% to 84%. The metre quadrat was placed on four different bedding planes, and 30 lonestones were noted in a total area of 4 m^2, whereas at Fossil Cliffs a total of 14 lonestones were noted within 3.2 m^2. Most Satellite Island lonestones are small but one subrounded boulder of porphyry measured 0.41 x 0.22 m and an angular boulder of schist measured 0.2 x 0.1 m. Another notable feature is the thinness of this section in contrast to the Fossil Cliffs section.



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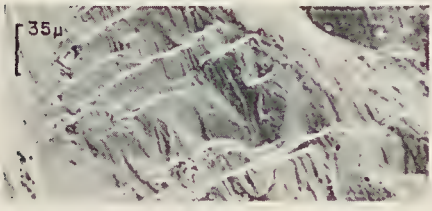

B

PLATE 1- Scanning Electron Micrographs.
A. Quartz grain from basal limestone of Darlington Limestone, Satellite (Woody) Island.
B. Quartz grain from bed WD-19, Darlington Limestone, Fossil Cliffs, Maria Island.

Fine sand-size grains of quartz obtained from insoluble residues were photographed under the Scanning Electron Microscope (pl. 1). Occasional grains show clean conchoidal fractures similar to the features Krinsley and Doornkamp (1973) attributed to glacial crushing.

Of the 369 fossils and fragments exposed within the metre quadrats, 3% were *Eurydesma*, 19% spiriferids, 38% ramose *Stenopora*, 11% lacy bryozoans, 3% pectenoid clams, 6% platy bryozoans, and the remaining 20% consisted of lonestones and fossil fragments.

Thin sections contain numerous Foraminifera, including *Nodosaria, Geinitzina(?)* and the encrusting form, *Calcitornella stephensi*. Internal moulds of linear uniserial Foraminifera (possibly *Nodosaria*) are common in the insoluble residues.

Banks *et al.* (1957) stated that the Darlington Limestone of Satellite (Woody) Island was deposited in deeper water than that of Maria Island. Several points favour this theory: the paucity of *Eurydesma*, the thinness of the section, the high percentage of limestone, and the relatively large numbers of *Nodosaria*. Contrarily, Crespin (1958) quotes J.A. Waters who believes that *Calcitornella* inhabited warm, moderately shallow waters. The theory that encrusting Foraminifera are indicative of high-energy environments seems not to apply universally to *Calcitornella*.

On two bedding planes there appears to be an alignment of ramose *Stenopora*. The average bearing of the alignments on the lower bed is 73°, and on the upper, 272°. It is believed that these bearings represent the approximate directions from which the currents came. Banks (1962) found that in the underlying Quamby Group, alignment of zoaria of *Stenopora* indicated that currents came from the southwest.

The Darlington Limestone is overlain by an incomplete section of Bundella Mudstone.

Glenorchy

Concerning a hole drilled near Glenorchy, Leaman (1976) stated: "Drilling has proved at least 74 m of this formation [Bundella Mudstone, including Darlington Limestone] at West Glenorchy, and only the upper 27-30 m is sandy siltstone. The remainder is calcareous with some units of definite but impure limestone".

Glenlusk Road

The Golden Valley Group is exposed in a cutting on the Glenlusk Road about 4.5 km west of the Glenorchy borehole. The Darlington Limestone is about 30 m thick and the Bundella Mudstone about 33 m thick. As indicated by Sutherland (1964) the section is disturbed by minor faulting and has been somewhat altered by contact metamorphism.

In this section the Darlington Limestone may be divided into three lithologic units. The basal 5 m of fossiliferous mudstone is unevenly bedded. The middle 15.5 m contains unevenly bedded mudstone and siltstone with numerous lenses of fossiliferous limestone. The upper 10 m consists of somewhat altered fossiliferous silty limestone. In the section as a whole, the aggregate thickness of beds of limestone is about 8 m. Due to metamorphism the limestones are only slightly calcareous; however, they are identified by their grey colour, smooth weathered, face and the presence of calcareous fossils.

The limestone lenses, of which five or six are visible in the middle unit, are unusual. Although only two dimensions are visible in the road cutting, the long axes seem to trend northwesterly. In most lenses the beds below are bowed downward; in all the top is horizontal. One lens is composed of fossiliferous siltstone. All contain *Eurydesma* as well as spiriferids, pectenoids and bryozoans. A line of small lonestones continues beyond the feather-edge of some lenses. Interval 14 is typical, the limestone lens is 3 m long and a maximum of 0.27 m thick. It is crowded with disarticulated valves of *Eurydesma*, 90% of which are convex-up. The origin of these lenses is unclear. Possibly they represent diastems on which limestone accumulated in pre-existing depressions. On the other hand, they may represent lime mounds or shell banks. If so, the weight of the mound may have caused it to be depressed into the sediment below. Large numbers of the fossils seem

to be broken and many are fragments, which suggests a high-energy environment. Possibly one or more of these breaks are related to the notable stratigraphic break in the Darlington Limestone at Fossil Cliffs.

Compact silty mudstone beds in the top 2.5 m of the Darlington Limestone may be altered limestone. Moulds of disarticulated *Eurydesma* and other fossils are mainly convex-down. This suggests deposition in a low-energy environment, possibly deeper water. Lonestones are smaller and fewer than in nearby sections. Most are associated with beds in the middle unit of the section. Small rounded pebbles of very dark slate or hard shale are common. These may have been derived from Cambrian or Precambrian rocks which today crop out to the southwest. The relative paucity of lonestones in this section suggests that the area may have been distant from land.

The overlying Bundella Mudstone is about 32.5 m thick (Sutherland 1964). It consists of yellowish siltstone in alternate massive and fissile units. The fissile units contain many bryozoans, and some spiriferids, *Eurydesma*, *Strophalosia* and other fossils. Lonestone pebbles and boulders are present, especially near the top of the formation. The thickness of the Bundella Mudstone remains fairly constant between the Glenorchy borehole, Glenlusk Road and Maydena Range.

Maydena Range

The Golden Valley Group is exposed in the Maydena Range (Jago 1972). The Darlington Limestone is exposed along a logging road north of Burma Road on the property of the Australian Newsprint Mills Ltd. The outcrop consists of dark silty limestone and micaceous limy siltstone. Bedding planes are marked by bands of fossils. Jago measured a thickness of 3.7 m but the present writer observed a thickness of only about 2 m. The section appears to thin toward the south within a short distance. Local variations may account for the discrepancy in the two measurements.

The upper part of the Darlington Limestone is quite fossiliferous. Jago reported that spiriferids form 40% of the fauna, whereas *Eurydesma* forms about 5%. The *Eurydesma* shells are relatively small and more than half are convex-side down. As at the Glenlusk Road, pectenoids are common (15%). In addition to small rounded white quartz and quartzite pebbles, a notable feature is the presence of fragments of Gordon Limestone (Jago 1972). Today the Gordon Limestone crops out a few kilometres to the west and northwest of this exposure so that the source of some of the detritus may have been close by.

Below the Darlington Limestone is the Satellite Siltstone, the top of which is a non-calcareous grey mudstone with numerous bryozoans and *Strophalosia*. The Bundella Mudstone overlies the Darlington Limestone and is 32 m thick (Jago 1972). It consists mainly of sandstone with numerous pebbles. Several beds are quite fossiliferous. The Bundella Mudstone at Maydena Range is coarser in texture than that at Glenlusk Road.

Low energy conditions during deposition of Darlington Limestone are indicated by the convex-down position of *Eurydesma* valves. The relative coarseness of the Bundella Formation suggests that the area was closer to the shore than was the Glenlusk Road area.

Poatina

The tripartite nature of the Golden Valley Group along the Western Tiers was reported by McKellar (1957). The Group consists of the Glencoe Formation (Brumby Formation of McKellar) at the base, the Billop Sandstone and the McRae Mudstone (Clarke and Banks 1975). The most complete exposure is along the Poatina Highway, downhill from the village of Poatina (Banks and Clarke 1973). Here the Glencoe Formation consists of about 16 m of dark, micaceous, poorly laminated, impure shale.

The Darlington Limestone is represented by two limy layers in the Glencoe Formation about 14 m apart stratigraphically. The lower layer consists of 0.19 m of very silty "limestone" with about 77% insoluble residue. It contains numerous spiriferids (60% of the fauna), *Eurydesma*, and lacy bryozoans on the bedding planes. Scattered lonestone

pebbles are present. The upper limy layer consists of limestone nodules 20 mm to 0.1 m thick which contain spiriferids and *Strophalosia*. The 14 m of strata between the two limy beds consists mainly of silty shale with spiriferids and lacy bryozoans. McKellar (1957) who studied both drill hole and surface sections reported 1.5 m of limestone in the Glencoe Formation. Lonestones are common in the limy layers but not in the non-calcareous layers. Possibly warmer water temperatures promoted precipitation of calcium carbonate and at the same time caused the melting of pack ice and calving of glaciers.

The Billop Sandstone consists of about 5.6 m of grey slightly calcareous sandstone and siltstone. It contains numerous rounded and subrounded pebbles of quartzite. McKellar (1957) stated that *Calcitornella* encrusts the upper surface of many of these pebbles, and that numerous fragments of brachiopods are present. The presence of encrusting Foraminifera suggests relatively slow deposition of sediment.

The McRae Formation was described by McKellar (1957) from both drill hole and surface data. It is 36 m thick and consists mainly of micaceous, pyritic mudstone with some beds of marl and sandstone. The upper part, which is mainly mudstone, contains bands of pebbles with macrofossils alternating with finer detritus. Banks (1962) suggested that these are turbidity current deposits. The McRae Formation does not contain the Darlington Limestone fauna.

Quamby Brook

The Quamby Brook locality is about 25 km northwest of Poatina. It was from this area that Wells (1957) proposed the name Golden Valley Group for strata that lie between the Quamby Mudstone and the Liffey Sandstone.

The Glencoe Formation is well exposed in a headwater branch of Quamby Brook above a bridge on the forest road to Liffey. Here the writer measured 22 m of dark siltstone, some of which emits a foetid odour when fractured. The thickness agrees with that reported by Pike (1973). Several layers contain numerous *Eurydesma*, pectenoid clams, lacy and ramose bryozoans, and many spiriferids. In a siltstone bed 5.5 m below the top of the Formation, about 75% of the shells are *Eurydesma*, many of which have articulated valves. Disarticulated valves are mainly convex side-down. Northward along the strike this layer contains fossiliferous limestone. A grab sample of this limestone contains 3.4% insoluble residue. Lonestones of metamorphic rocks are common in the lower part of the Glencoe Formation. They range in size from pebbles to boulders. Core drilling in the Golden Valley Group in this area (Clarke 1968) revealed six limestone beds aggregating 0.63 m in a thickness of 27 m. Clarke reported the presence of *Calcitornella* on the inner surfaces of spiriferid valves.

The Glencoe Formation in the Quamby Brook section is more silty and, except for the basal portion, contains fewer lonestones than the Poatina section. This may suggest that the Quamby Brook area was closer to the source of the detritus, but that the source was not delivering much coarse debris. Some of the sediment seems to have been derived from an island that lay between Frankford and Beaconsfield (Clarke and Banks 1975, p.460). Additional detritus may have come from the west (Banks 1962, fig.30d) or from the basement high at Quamby Brook. The foetid odour and the presence of ostracods suggest a restricted environment for the siltstone beds. Disarticulated valves with the convex side-down as well as articulated shells indicate a low-energy environment.

The underlying Quamby Group in this area is thought to have been deposited in deeper water than the Glencoe Formation. It was derived in part from islands to the north (Banks 1962).

The Billop Sandstone consists of about 5 m of poorly-bedded, medium to coarse-grained sandstone with numerous fossils and many pebbles. The lower layers form a prominent ledge in the creek. The pebbly Billop Formation at Quamby Brook and Poatina, and a pebbly sandstone in the same position at Maydena Range may be a response to an uplift in the area to the west.

At Quamby Brook the overlying McRae Formation is not well exposed but consists of about 34 m of mudstone and siltstone.

Lilydale area

The Golden Valley Group crops out in the Lilydale-Karoola area north of Launceston. Banks (1962, fig.30d) indicated that it is 64 m thick and that the Darlington Limestone is one metre thick. The best exposure is in the railway cutting between Lilydale and Downie (Longman 1966). Longman reported that the Darlington Formation is 9 m thick. The actual limestone appears to be considerably thinner. Some of the "limestone" contains as much as 80% insolubles.

The Darlington Formation consists of dark grey calcareous shale and very silty limestone which contain *Eurydesma*, small ramose *Stenopora*, *Strophalosia*, and abundant *Calcitornella*. Some of the latter encrust bryozoans. Disarticulated valves of *Eurydesma* are oriented convex-up and some are vertical. Lacy bryozoans are common in the shaly beds. The limy beds are overlain by dark grey claystone and silty clay shale which are sparingly fossiliferous. The closest lithologic counterpart of the Lilydale locality is the Poatina section. This may mean that the environment on the two sides of the basin was similar at this time. Fewer lonestones were observed in the Lilydale section than in any other. Those present consist of pebbles of dark quartz, quartzite and other metamorphic rocks.

A limited section occurs near Karoola in an abandoned quarry on the Karoola-Bangor road (Marshall 1969), about 7 km west of the Lilydale exposure. The Darlington Limestone equivalent is about one metre thick (Longman 1966). The macrofossils are smaller than those at Lilydale and ostracods are present.

The shore of the "Golden Valley sea" lay a few kilometres east of Lilydale (Banks 1962). The Darlington Limestone thins rapidly against this ancient shore (Longman 1966). An island west of the Tamar Estuary (Clarke and Banks 1975, fig. 33.4) formed the western shore.

If *Calcitornella* is characteristic of warmer waters, it may indicate that this area, which was close to shore represents shallow water with a minimum of floating ice. The latter is suggested by the paucity of lonestones. Occasional grains of glauconite in the limestones of the Lilydale section also suggest warmer waters with slow deposition.

On the north coast of Tasmania stratigraphic equivalents of the Darlington Limestone occur in portions of the Masseys Creek Group (Gee and Legge 1974). The writer examined three exposures: Middle Arm Creek, West Arm of Tamar (Anderson Creek), and Port Sorell.

Middle Arm

This exposure occurs about 40 m north of the old lime kiln on the east side of the mouth of the Middle Arm of the Tamar Estuary (Gee and Legge 1974). It consists of about one metre of silty limestone overlain by at least 0.4 m of conglomerate. The limestone contains about 12% insolubles. Macrofossils and fragments present on 0.15 m^2 of vertical face consist of 50% unidentified fossil fragments, 21% pebbles and boulders, 20% *Eurydesma*, 5% spiriferids, 3% platy bryozoans, plus many *Calcitornella*. The shells are mainly single valves, convex-up. From the topmost layer of limestone, 23 lonestones were collected from one linear metre. Table 2 shows their nature and possible source. The calcareous fragments may have been derived from Ordovician strata which today are exposed 5 km to the west near Beaconsfield. Devonian granite is exposed today 30 to 40 km to the east. The greatest number of lonestones seem to have been derived from the Mathinna Formation or other Early Palaeozoic rocks which today crop out 6 km to the west and in a large area about 12 km to the east. Either of these areas may have been the source of the fragments; however, the relatively large number at Middle Arm and the relatively small number at Lilydale and Karoola suggest that the Frankford-Beaconsfield island may have been the more important source.

TABLE 2

TYPES OF PEBBLES
taken along a stretched line one metre long on the outcrop of Interval 3. Middle Arm of Tamar section.

		Number of specimens	Rock type	Possible sources: Ordovician	Early Palaeozoic	Devonian
Subangular to angular	Very large pebbles 30-60 mm	1	Grey quartz schist, 60 mm diameter		x	
		3	Grey quartz schist, fine-grained		x	
		1	Dark micaceous quartz schist		x	
		2	Grey quartzite		x	
		1	Mica phyllite		x	
		1	Grey altered rock, green mineral, quartz, clay			
Rounded to subrounded		1	Quartz sandstone, poorly sorted		x	
		1	Weathered chert nodule with calcareous centre, 20 x 50 mm	x		
	Large pebbles <30 mm	1	Colourless quartz			
		2	Grey quartz			
		1	Grey quartzite		x	
		1	Layered quartzite		x	
		1	Weathered yellow quartzose rock			
		1	Weathered yellow claystone			
		1	Silty grey limestone with micro-veinlet	x		
		1	Phyllite		x	
		1	Muscovite schist		x	
		1	Fine-grained banded quartzite			
		1	Dark grey granite (quartz, light coloured feldspar)			x

Total 23 fragments

A conglomerate above the limestone consists of a calcareous matrix with pebbles and boulders the lithology of which is similar to the lonestones in the limestone below.

In a road cut a short distance south of this exposure, brown siltstone with lenses of limestone containing many *Strophalosia* lies at a higher stratigraphic position than the conglomerate.

In the Middle Arm section the Darlington Limestone is characterized by poor bedding and numerous shells that are at odd angles to the bedding. This suggests shallow water conditions of deposition.

West Arm of Tamar

This section lies along the lower end of Andersons Creek and near the mouth of Masseys Creek. Here the Masseys Creek Group has a thickness of 290 m (Gee and Legge 1974). The section is not completely exposed but supplementary data have been obtained from holes drilled by the Tasmanian Geological Survey and correlated by M.J. Clarke (in Gee and Legge 1974). The Darlington Limestone fauna (Faunizone 2) is present in a grey fossiliferous mudstone which is visible at the mouth of Masseys Creek at low tide (M.J. Clarke,

oral communication). The writer was guided to this locality by M.R. Banks. The mudstone lies 120 m stratigraphically below the Liffey Sandstone and some 10 m below a band of large calcareous concretions. The position of the fauna may be obtained by comparing the diagram in Clarke and Farmer (1976, p.96) with that of Gee and Legge (1974, fig.15). The latter stated that the mudstone contains *Deltopecten*, *Eurydesma*, *Grantonia*, *Pseudosyrinx* and *Strophalosia*.

Port Sorell

An extensive stratigraphic section of the Masseys Creek Group occurs in the estuary at Port Sorell. It is exposed above low tide level on the west side of "The Tongue". The section is interrupted by a fault (Gee and Legge 1974). These authors reported that here the total thickness of the Masseys Creek Group is a minimum of 350 m and a maximum of 520 m, assuming no duplication by faulting. The portion of the section north of the fault, herein called the Lower Port Sorell section, is 56 m thick between the lowest exposed limestone and the highest. It consists of silty limestone interbedded with very fine-grained sandstone and mudstone. Many lonestones are present, most of which are in the limestone beds. Many layers contain fossils and fossil fragments. Spiriferids and bryozoans are common. The largest lonestones observed in the Golden Valley-Masseys Creek Groups are in the Port Sorell section.

The portion of the section south of the fault, herein called the Upper Port Sorell section is about 12.6 m thick. It consists of two limestone units with sandstone and claystone between. The upper limestone bed is 1.7 m thick and contains about 30% insolubles. The weathered surface has a "sandpaper" appearance. A quadrat 0.21 m^2 in area was placed on a bedding plane of this limestone. Of 100 specimens within the area of the quadrate 40% were lonestones, 29% ramose bryozoans, 20% spiriferids, 4% *Eurydesma*, 4% *Strophalosia*, 1% lacy bryozoans, and 1% fossil fragments. Near the middle of this same limestone bed there is a coquinite of *Eurydesma*, with some spiriferids and pectenoids which lie both convex-up and convex-down. The base of this coquinite is a mass of *Stenopora* and shell fragments which rest on the claystone beneath.

It is thought that the limestone of the Upper Port Sorell section is equivalent to the Darlington Limestone.

As indicated by the cross-section in Clarke and Banks (1975) the Liffey Sandstone overlies increasingly older beds westward in northern Tasmania so that the Darlington Limestone is not found in this area.

Reports of Palaeozoic strata at depth in the Bass Basin and Gippsland Basin (McPhee 1975) lead to the speculation that the Permian marine basin may have extended northward and northeastward into these areas. The Bassian Rise may have been a barrier but might have only partially restricted migration of marine faunas to and from the southern New South Wales basins. Two facts suggest that the Permian strata may have extended into the Bass Basin: the thick sequence of strata in the West Arm and Port Sorell sections; and the presence of relatively pure limestone beds in the Masseys Creek Group in both of these sections.

Western Tasmania

In the vicinity of Lake St Clair the equivalent of the Golden Valley Group has been reported in a portion of the Wallace River Group (Banks 1962). On the upper Alma River, near Goulds Sugarloaf, a stratigraphic section (Gulline 1965) shows 97.5 m of Wallace River Group which includes 3 m of limestone and some 79 m of fossiliferous mudstone with pebbles. The limestone is equivalent to the Darlington Limestone.

In the area of Cradle Mountain the Golden Valley Group is often missing. Terrestrial conglolerates of Permian age lie immediately to the south (Banks 1962). The source of some of the Golden Valley sediments was in this upland.

On the west coast possible Golden Valley equivalents have been reported from Point Hibbs (Banks and Ahmad 1962). About 142 m of cyclic sediments consist mainly of conglomerate and siltstone. The pebbly beds contain fossils such as *Eurydesma*, *Keeneia* and *Stenopora*. In a fossiliferous siltstone in one cycle a bed of fossiliferous limestone 0.46 m thick is present. Banks and Ahmad (1962) suggested that this may be the Darlington Limestone equivalent. About 100 m below the limestone, cross-bedded sandstone indicates currents from 225° and ripple marks trend 340°. These strata may be equivalent to the Quamby Group.

A stratigraphic succession on Mt Sedgwick, north of Queenstown, contains a bed of limestone 0.5 m thick. Banks and Ahmad (1962) suggest that it may correlate with the Darlington Limestone.

An east-west trending seaway across Tasmania in Golden Valley time is postulated (fig. 1). This separates the northwest upland from the inferred southwest upland. The presence of the seaway is suggested by the distribution of Darlington Limestone and related strata at Point Hibbs, Mt Sedgwick, and the Lake St Clair area. In addition, discontinuous deposits of other Permian strata occur in this area (Banks 1962). If Permian strata originally covered the area, uplift of the horst in western Tasmania (Banks 1962, fig.39) may have raised the strata to elevations which permitted erosion to remove much of the section.

PALAEOENVIRONMENT

The Late Palaeozoic glaciation in Tasmania has been known for many years. Palaeomagnetic studies by Embleton (1973) placed the Permian South Pole in the present Great Australian Bight. Among those who have published palaeogeographic maps to show the position of Tasmania with respect to Gondwana glaciation are Lacey (1975), Elliot (1975) and Crowell (1978).

During the Tamarian time in Tasmania there were at least three, and probably four, sources of sediment (fig. 1): (i) the northeast and east, including portions of Maria Island, (ii) the Cradle Mountain and northwest upland (Banks 1962, fig.30D), (iii) the Beaconsfield-Frankford island (Clarke and Banks 1975), and (iv) a postulated area in southwestern Tasmania (fig. 1). Although no tillite of Tamarian age has been identified on these uplands, probably at times all the larger areas bore glaciers from which icebergs and pack ice were derived. Clarke (1968) postulated the presence of a dry-base glacier near Quamby Brook, and Banks (1962) postulated piedmont glaciers in the uplands, both postulates applying to pre-Darlington Limestone time. Clarke and Banks (1975, p.460) illustrated conglomerates near former shorelines.

Lonestones

Conglomeratic layers are present in the Golden Valley and Masseys Creek Groups and should not be confused with lonestones. Fine detritus as well as lonestones, which range in size from pebbles to boulders nearly a metre in length, are scattered through the Darlington Limestone. Some lonestones are in bands; however, most are isolated and embedded in the underlying strata. The latter are thought to have been dropped into soft sediment from floating ice. Clearly striated or faceted lonestones were not observed by the writer but faceted pebbles have been reported by Banks (1962). Many lonestones are subrounded to subangular which suggests that at one time they were transported by water. These could have been frozen into pack ice along former beaches or bars.

The sources of some of the lonestones have been referred to by Banks (1962). Fragments from the Gordon Limestone, Mathinna Formation and Devonian granite are distinctive. Future studies may link the numerous metamorphic rock fragments with their sources.

In the Darlington Limestone, lonestones seem to be most abundant in the limy layers, and at Fossil Cliffs lonestones are more abundant in the spiriferid calcirudites

("fossil hash") than in the coquinites or silty layers. A possible explanation for this phenomenon may be that the high energy which fragmented the shells and concentrated them, may have caused the pack ice to break up and loose the rock fragments. Milliman (1973), however, stated that the CO_2 content of water is increased by turbulence, especially in polar seas, which would tend to decrease the amount of limy precipitation.

Quartz grains from several localities were examined under the scanning electron microscope. Some grains showed conchoidal fracture which is characteristic of glacial crushing (pl. 1).

Water temperature

The Darlington Limestone contains about 30 genera of macrofossils, but the bulk of the fauna consists of a few genera. In many limy beds the valves of *Eurydesma* comprise more than half of the fossils. Spiriferid brachiopods are abundant and, in the silty layers, fragments of ramose and lacy bryozoans are abundant. Numerous individuals of relatively few taxa could be explained by the fact that the environmental conditions departed from the optimum for most taxa concerned (Thienemann's Rule). In this case the conditions could have been low water temperature, low salinity or both. Cold water is suggested not only by the lonestones but by the presence of a foramol fauna (Lees 1975). Lees stated that in shelf associations a mollusc-bryozoan benthonic foraminiferal fauna can occur at low temperatures, particularly where the salinity is below that of normal seawater.

Today much of the carbonate sediment in high latitudes is in the form of shell debris (Chave 1967). This is not inconsistent with the large accumulations of shell debris in portions of the Darlington Limestone. Foster (1974) indicated that brachiopods in the present Ross Sea (Antarctica) show an inversed relationship between density of individuals and diversity of types. The largest population and maximum shell sizes occur along the front of the ice shelf. Although the first part of this analogy applies to the Darlington Limestone, evidence for the latter part is not obvious.

Oxygen isotope data obtained from *Eurydesma* and *Trigonotreta* shells from southeastern Tasmania indicate cold water ("glacially derived") conditions for these specimens (Green *et al.* 1979).

The foraminifera yield conflicting evidence as to temperature. *Calcitornella* is believed by some (Crespin 1947, p.29) to represent warm water conditions whereas the genus *Hippocrepinella* is found today in both the Arctic and Antarctic oceans. Both genera occur in the Darlington Limestone (Banks 1962). Although *Calcitornella* is present in many parts of the Tasmanian Basin it seems to be most abundant in the Lilydale-Karoola and Middle Arm sections. If *Calcitornella* is indeed characteristic of warm shallow water, the portion of the Basin north of Launceston may have been somewhat warmer than the less restricted parts of the Basin. Encrusting foraminifera commonly are associated with high-energy environments.

Hydraulic energy

Energy in the form of waves and currents expresses itself in the sorting of sediments and in various sedimentary structures. The Darlington Limestone shows very poor sorting at most localities and few sedimentary structures. The carbonate is mixed with detritus of various sizes. Some of the best sorting appears to be in the coquinites in the Fossil Cliffs. Here large numbers of *Eurydesma*, pectenoids and spiriferids are heaped together with a minimum of matrix. It is apparent that these layers represent death assemblages developed by current and wave action. The absence of juveniles lends credence to this theory. It is postulated that these *Eurydesma* coquinites were broad shell ridges in relatively shallow water where shells were amassed by wave action. Pectenoid clams may have been derived from lagoons shoreward from the ridges. A modern analogue may be found on barrier beaches where great numbers of the heavy valves of the clam *Mercenaria* are heaped up by storm waves.

At Fossil Cliffs coquinites formed at successively higher stratigraphic levels as deposition continued; however, above the erosional(?) break (fig. 2, Int.21, EFC) no coquinite occurs. At this time conditions became less favourable for *Eurydesma*, but spiriferids became more abundant. Possibly these conditions were due to a shallowing of the water. Wave action churned the bottom and spiriferid calcirudite ("fossil hash") formed. Pack ice breaking up in shallow water provided numerous lonestones.

Directional properties

Indications of current direction are rare in the Darlington Limestone. The orientation of umbos of single valves of *Eurydesma* at Fossil Cliffs indicate northerly, southerly and easterly currents but such orientation may not indicate prolonged current activity in any one direction. Small scale cross-bedding is present on the east side of South Maria Island. Imbrication of *Stenopora* zoaria at Fossil Cliffs suggests northeasterly currents (Banks 1962). The alignment of ramose bryozoans at Satellite (Woody) Island indicates northeasterly and southwesterly currents. Cross-bedding and ripple marks in pre-Darlington Limestone strata at Point Hibbs indicate southwesterly currents (Banks and Ahmad 1962).

Nearly all of these directional properties indicate a general southwest-northeast motion of waters. If, as appears to be the case, the Tasmania Basin was open to the south and restricted to the north, these alignments are not surprising. The palaeogeographic map of the Early Permian by Crowell (1978) shows ocean currents from a direction which is now south of Tasmania.

Nearly all the localities where evidence of current action has been found lie on the outer edges of the Tasmanian Basin. Possibly strong current and wave action was impeded in the central part by the shape of the basin as well as by islands, bars and, at times, by pack ice. A possible distribution of bottom energy in the basin during Darlington Limestone time might resemble the cross-section (fig. 3). The typical shelf-sea pattern of sedimentation is complicated by the presence of detritus dropped from floating ice.

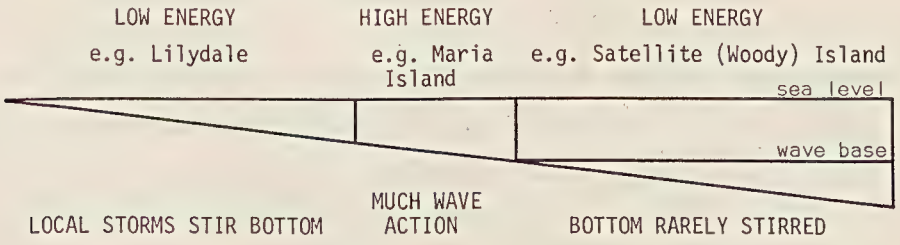

FIG.3- Diagrammatic representation of hydraulic energy conditions in Darlington Limestone time.

Depth of water

Banks (1962) stated that the grain size of the Golden Valley Group decreases toward the west and northwest which suggests an easterly source and a shallower sea to the east. The presence of numerous bryozoans in sections such as Poatina and Quamby Brook may indicate relatively deep water. Studies of modern bryozoans off South Australia (Wass *et al.* 1970) indicate that reteporiform (lacy) types are found in quiet water at depths greater than 115 m and that viniculariform (ramose) types are common at depths less than 55 m where current and wave action are present. Elias (1936) believed that bryozoans ranged from 23 to 50 m in depth in the Early Permian seas of Kansas.

Although thickness of shells of bivalves has been correlated with shallow water and strong abrasion (Stanley 1970) this is not universal.

Some of the minute borings in the valves of *Eurydesma* at Fossil Cliffs are in a size range comparable to borings of blue-green algae. If algae were present, the shells, at some time, must have been in the photic zone.

Cyclic sedimentation

Cyclic and rhythmic sedimentation has been noted at several stratigraphic levels in the Permian of Tasmania. Cycles in the Berriedale Limestone and Grange Formation were noted by Brill (1956). The Berriedale cycles were restudied by Rao (1979) who attributed them to glacial fluctuations.

In the Darlington Limestone at Fossil Cliffs eleven cycles were described by Banks (1957). Banks and Hale (1957) noted the alternation of fissile and non-fissile siltstone in the Bundella Mudstone at Hobart. Sutherland (1964) noted similar alternations in the Bundella Mudstone along Collinsvale Road. Larger cycles were mentioned by McKellar (1957) in the Golden Valley Group at Poatina. Four thick cycles in the Golden Valley Group were found at Point Hibbs by Banks and Ahmad (1962).

Most explanations of the cycles are based on waxing and waning of glaciers in Gondwana. Contrarily, Crowell (1978) stated that, although there may be more than one cause, the cycles are probably related to sea-floor spreading which caused eustatic changes in sea level. An interesting theory involving wet-base and dry-base glaciers to explain the marine sediments of the Permian of Tasmania has been proposed by Carey and Ahmad (1961). They postulated that rhythmic marine sedimentation could be produced near the end of a dry-base glacier.

The present writer believes that glaciation may be regarded as the primary cause of these cycles with tectonic movements providing local effects. Until more precise marker beds within the Golden Valley Group are found, it will be difficult to determine lateral gradations within the unit and to make long distance correlations.

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A TASMANIAN LANDLOCKED POPULATION OF THE NORMALLY DIADROMOUS FISH *GALAXIAS MACULATUS* (JENYNS)

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(with two tables and one text-figure)

ABSTRACT

ANDREWS, A.P., 1982 (31 viii): A Tasmanian landlocked population of the normally diadromous fish *Galaxias maculatus* (Jenyns). *Pap. Proc. R. Soc. Tasm.*, 116: 85-90. ISSN 0080-4703. Tasmanian Museum and Art Gallery, Hobart, Tasmania.

A landlocked population of the normally diadromous fish *Galaxias maculatus* is recorded for the first time from Tasmania. The differences between the landlocked population and normal diadromous *G. maculatus* are examined and discussed. The association with other species together with the probable mode of origin of the landlocked population are considered.

INTRODUCTION

The taxonomy of *G. maculatus*, both at the generic and specific levels, has been in a state of confusion virtually since its description. From material collected during the voyage of Darwin's "Beagle" Jenyns (1842) described *Mesites maculatus* and *M. alpinus* from South America and *M. attenuatus* from New Zealand. All three species were included in *Galaxias* by Valenciennes (1846) but later Ogilby (1899) proposed a new genus *Austrocobitis* for *G. attenuatus* and an additional Australian species. *Austrocobitis* was intended as a substitute for *Mesites*, which was found to be preoccupied by a genus of beetles, and has been rejected by most recent writers (see Scott 1966) but retained by Whitley (1933) although in a different sense from that originally proposed.

Stokell (1966) considered the *G. attenuatus* of Australia and New Zealand and the *G. maculatus* and *G. alpinus* of South America, concluded that they were only subspecifically distinct and applied the name *G. maculatus* on the grounds of page precedence. Stokell's less than fortunate choice of name has been criticised by McDowall (1967a) and Scott (1968) but as McDowall (1967a) has pointed out Stokell is first revisor and the name *G. maculatus* must now be used. However some recent writers (Green 1969; Scott 1971, 1974; Maclean 1974; Thomson 1977) have retained *G. attenuatus*.

Further confusion exists in that *G. maculatus* has been recorded from Australia, New Zealand, Lord Howe Island, Chatham Islands, Chile, Argentina, Tierra del Fuego and the Falkland Islands (McDowall and Frankenberg 1981) with both diadromous and lake isolated populations having been recorded from mainland Australia, New Zealand and South America (McDowall 1972). The existence of such widely dispersed populations together with lacustrine variates, has led to populations in various areas being repeatedly redescribed as new species. McDowall and Frankenberg (1981) listed a total of thirty-five names which at one time or another have been applied to populations of *G. maculatus*. Even after much recent study there is still not a general consensus among taxonomists as to whether *G. maculatus* represents one species (McDowall 1972), more than one species (Scott 1968; Campos 1974) or more than one subspecies (Stokell 1966). Some lacustrine populations have also been regarded as distinct. Stokell (1964) described *G. parrishi* from Victoria, McDowall (1967b) described *G. gracilis* and *G. usitatus* from New Zealand and Campos (1974) applied the name *G. alpinus* to freshwater limited populations in Chile. Pollard (1971b) examined a number of landlocked Australian populations and concluded that they were best regarded as "ecological races" rather than distinct species.

This conclusion was supported by McDowall (1972) who concluded that the only valid lacustrine species was *G. gracilis* of New Zealand. The results of the present study appear to support this conclusion.

MATERIALS AND METHODS

In a previous study (Andrews 1976) it was stated that no Tasmanian populations of *G. maculatus* were encountered which could be regarded as landlocked. Subsequently a sample of twenty-one specimens were obtained from Bowlers Lagoon, an isolated sand dune lake in northeastern Tasmania (map reference EQ780760) located some 2 km from the coast and 1 km east of the Ringarooma River (fig. 1). All specimens were recovered from fyke nets set by a commercial eel fisherman and were fixed in the field in 10% formalin and subsequently transferred to 70% ethanol. Seven of the specimens were cleared and stained for osteological study.

Fig.1 Locality Map

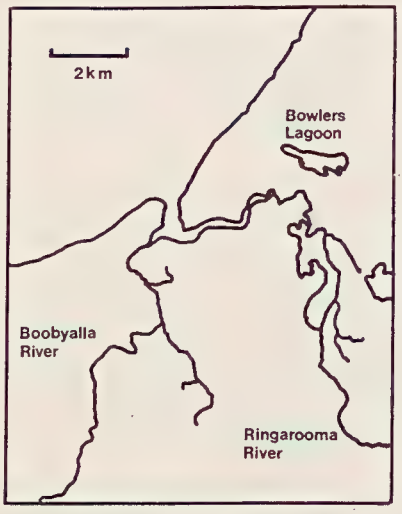

FIG. 1.- Locality map.

Methods of measurement and counts followed those adopted by Andrews (1976) except that segmented fin rays only were counted whether branched or unbranched. For meristic and morphometric comparison a group of twelve *G. maculatus* was selected from samples of diadromous Tasmanian populations, chosen largely at random, to form a group of comparable standard length range to the Bowlers Lagoon material which varied from 99.6 mm to 147.0 mm standard length.

RESULTS

Morphometric and meristic data are summarized in tables 1 and 2. Morphometric comparison indicated that the landlocked population differed little from typical *G. maculatus* apart from a slight tendency towards smaller paired fins, a narrower caudal peduncle and a wider head. Values of Student's "t" were calculated using a pooled estimate of the variance in both the diadromous and landlocked populations and in only one proportion was the 5% level of significance exceeded. Meristic data tended to indicate fewer vertebrae, fewer dorsal, anal and caudal fin rays and an increase in pectoral and ventral fin rays and gill rakers in the landlocked population. However these differences were small and in only one case, anal fin rays, was the 1% level of significance exceeded. With the exception of vertebrae, the landlocked population exhibited a greater range of variation in

almost all characters examined. The reduction in caudal and increase in ventral fin rays is unusual in that *G. maculatus* normally exhibits high stability in both these characters (McDowall 1972, Pollard 1971b), so much so that they were not tabulated by Andrews (1976). The Tasmanian *G. maculatus* examined by McDowall and Frankenberg (1981) exhibited eight rayed ventrals in 5% of cases, considerably less than the 10.5% of occurrences in the Bowlers Lagoon material.

TABLE 1

MORPHOMETRIC VARIATION BETWEEN THE LANDLOCKED AND DIADROMOUS *G. MACULATUS*. Numerator written as a percentage of the denominator. ($\bar{x}$ = sample mean, S.D. = standard deviation, t = Student's t).

	Landlocked				Diadromous				
	min.	max.	$\bar{x}$	S.D.	min.	max.	$\bar{x}$	S.D.	t
Head length/standard length	16.6	20.4	18.6	0.95	17.4	20.3	18.6	0.84	0.11
Snout-dorsal origin/standard length	73.5	78.2	76.3	1.30	74.9	79.1	76.6	1.10	0.63
Snout-ventral origin/standard length	48.7	51.2	49.9	0.75	47.1	50.7	49.4	1.03	1.47
Pectoral length/pectoral base-ventral origin	30.7	47.5	38.0	4.10	36.6	43.2	39.7	2.05	1.31
Ventral length/ventral base-anal origin	31.8	45.3	37.5	3.52	36.5	42.1	38.7	1.90	1.06
Depth caudal peduncle/length caudal peduncle	40.4	53.0	45.7	4.17	41.3	50.0	46.5	3.06	0.56
Length caudal peduncle/ standard length	13.7	15.0	14.3	0.53	13.7	15.3	14.5	0.57	0.95
Eye diameter/head length	17.3	22.3	20.2	1.29	19.1	23.5	20.7	1.20	1.04
Upper jaw length/head length	24.0	35.9	29.3	2.61	26.7	32.0	29.3	1.54	0.01
Lower jaw length/head length	21.0	30.8	25.9	2.46	23.4	30.0	26.5	1.72	0.72
Gape width/head length	31.5	42.8	35.2	2.65	27.5	37.4	32.3	2.69	2.84
Interorbital width/head length	38.2	45.2	41.2	2.18	37.6	42.7	40.6	1.53	0.81

LIFE HISTORY AND ASSOCIATION WITH OTHER SPECIES

Pollard's (1971a) studies on landlocked *G. maculatus* indicated that spawning took place during late winter and early spring in contrast to diadromous populations which normally spawn during autumn and early winter (Burnet 1965; McDowall 1968). The Tasmanian landlocked material was collected in autumn (II.IV.1979) and females were found to contain partially developed eggs 0.5 mm diameter which would seem to indicate a late winter or early spring spawning presumably when water levels are at a maximum following winter rains.

Two other species were recorded in association with the landlocked population, a commercial species of eel (*Anguilla* sp.) and the southern pygmy perch *Nannoperca australis* Günther, a species not recorded in association with *G. maculatus* in a previous study (Andrews 1976). However as all populations previously studied were diadromous and as *N. australis* favours a stagnant weedy habitat (Llewellyn 1980) this is hardly surprising.

TABLE 2

MERISTIC VARIATION BETWEEN THE LANDLOCKED AND DIADROMOUS *G. MACULATUS*. Bracketed numbers indicate frequency of occurrence. ($\bar{x}$ = sample mean, S.D. = standard deviation, t = Student's t)

	Landlocked	$\bar{x}$	S.D.	t
Dorsal rays	8(4), 9(6), 10(10), 11(1)	9.4	0.84	
Anal rays	13(3), 14(11), 15(7)	14.2	0.66	
Caudal rays	15(1), 16(20)	15.9	0.22	
Pectoral rays	12(9), 13(22), 14(9), 15(1)*	13.0	0.73	
Ventral rays	7(38), 8(4)	7.1	0.50	
Gill rakers	14(3), 15(2), 16(4), 17(3), 18(2), 19(1), 20(1)	16.4	1.70	
Vertebrae	57(1), 58(3), 59(2), 60(1)	58.4	0.90	
	Diadromous			
Dorsal rays	9(4), 10(8)	9.6	0.48	0.81
Anal rays	14(2), 15(7), 16(3)	15.1	0.64	3.75
Caudal rays	16(12)	16.0	-	0.17
Pectoral rays	12(10), 13(11), 14(3)	12.7	0.68	1.15
Ventral rays	7(23)	7.0	-	0.67
Gill rakers	14(1), 15(5), 16(4), 17(2)	15.6	1.73	1.45
Vertebrae	57(1), 58(2), 59(3), 60(5), 61(2)†	59.4	0.90	1.89

* absence of a fin in one specimen † data from Andrews (1976)

Scott (1971), who had earlier (1935; date cited in error as 1936 in Scott 1971; and 1942) claimed he could detect no specific differences between *N. australis* Günther and *N. tasmaniae* Johnston, later (1971) proposed subspecific distinction for the Tasmanian population which became *N. australis tasmaniae*. Scott's proposals were accepted by Scott *et al.* (1974) and Frankenberg (1974) but were not accepted by Lake (1971, 1978). Llewellyn, who had earlier (1974) accepted Scott's subspecific divisions, later expressly rejected them (Llewellyn 1980).

DISCUSSIONS AND CONCLUSIONS

Although almost morphologically indistinguishable from diadromous *G. maculatus* the landlocked population exhibited differences in the form of meristic variation and instability in a number of characters and a change from the usual spawning period. The first observation of differences in populations of *G. maculatus* was by Jenyns (1842) who at the conclusion of his description of *G. maculatus* mentioned four other specimens from the upper regions of streams in Patagonia and drew attention to the differences exhibited by them. Jenyns then proceeded to describe *M. alpinus* from freshwater lakes in Peninsula Hardy, Tierra del Fuego as a distinct species on the basis of the larger eye and longer head although he admitted that it differed little from *G. maculatus*. Similarly he considered *M. attenuatus* from New Zealand to be distinct on the basis of the longer body, smaller head, mouth, eyes and teeth, and the more anterior insertion of the ventral fins.

Subsequent to Jenyns (1842) many nominal species have been described (see McDowall and Frankenberg 1981) largely on alleged morphometric differences. Stokell (1964) considered *G. parrishi* to be distinct on the basis of the low number of vertebrae and the presence of an abdominal keel. McDowall (1967b) described *G. gracilis* and *G. usitatus* largely on the basis of meristic variations. Pollard (1971b) considered *G. parrishi*, *G. usitatus* and *G. gracilis* differed from *G. maculatus* in having longer heads, larger eyes and fewer vertebrae and that the landlocked Lake Modewarre form studied by him was intermediate between these three forms and typical *G. maculatus*. He also concluded that the

change from autumn to spring spawning in the Lake Modewarre form was due to environmental rather than genetic factors. McDowall (1972) again examined the problem and considered the effects of geographic and genetic isolation on the landlocked populations and the probable influence of environmental factors on the differences between them. That populations in different areas appeared to vary in different ways from each other was interpreted by McDowall as mosaic evolution. He concluded that biological species criteria failed to provide an adequate basis for taxonomic divisions and that morphological criteria had to be relied on instead. Thus he considered *G. alpinus*, *G. parrishi* and *G. usitatus* to be junior synonyms of *G. maculatus* although *G. gracilis* was retained as distinct on account of the disjunction between it and typical *G. maculatus* in a number of characters.

One aspect of the landlocked populations dealt with only in passing in recent studies is the length of time the various populations have been isolated. Pollard (1971a) indicated that Lake Modewarre had its origins during the Late Pleistocene or Holocene and McDowall (1972) in his discussion of South American landlocked populations commented, "their present isolation seems likely to ensure that with time they will continue to diverge from their parental stock and may ultimately attain a level of distinctness requiring taxonomic recognition, but this is not so at present." On the evidence presently available it would appear that the Tasmanian landlocked population is of fairly recent origin. The almost negligible morphological differences from typical *G. maculatus* and meristic instability, perhaps indicative of a reduced gene pool, all appear to indicate that the population has been recently derived from diadromous *G. maculatus*. The change in spawning period being probably due, as Pollard (1971a) has suggested, to environmental rather than genetic factors.

Bowlers Lagoon appears to have originated during the Holocene, some 6-8 000 years before present (A. Goede, pers. comm.), probably as an anabranch of the Ringarooma River, from which diadromous *G. maculatus* were recorded during the present study. Rising sea levels after the last glacial period apparently deflected the river mouth westwards resulting in the lagoon becoming isolated from the river by subsequent deposition.

If, as has been outlined above, the landlocked population is of recent origin then it seems reasonable to assume that those landlocked populations which show the greatest divergence from typical *G. maculatus* will be those isolated the longest. McDowall (1972) has pointed out that isolated populations tend to diverge ecologically and morphologically from each other as a result of genetic isolation, itself a product of geographic isolation, and sometimes genetic drift. If this is the case with the presently known landlocked *G. maculatus* then McDowall's (1972) conclusions are correct and taxonomic recognition is not required. The current exception, *G. gracilis* of New Zealand may in fact represent no more than the most divergent of the landlocked populations yet examined and as more such populations become known the taxonomic status of *G. gracilis* may require reappraisal.

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(ms. received 15.10.81)

LATE PLEISTOCENE MARINE MOLLUSCAN FAUNAS FROM FOUR SITES IN TASMANIA

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(with two tables and one text-figure)

ABSTRACT

COLHOUN, E.A., TURNER, E. and van de GEER, G., 1982 (31 viii): Late Pleistocene marine molluscan faunas from four sites in Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 91-96. ISSN 0080-4703. Department of Geography, University of Tasmania, and Tasmanian Museum and Art Gallery, Hobart, Tasmania.

Species lists of Late Pleistocene interglacial molluscan faunas and details of their occurrence are given for four sites in Tasmania. The faunas occur in former shallow coastal embayments, and inner and outer estuarine shallow water environments. All of the species are extant.

INTRODUCTION

During recent work on Quaternary sea level changes in Tasmania (van de Geer *et al.* 1979; van de Geer, in prep.) collections of marine molluscs were obtained from Broadmeadows and Montagu in northwestern Tasmania, and from Swansea and Mary Ann Bay in eastern Tasmania (fig. 1). Although moulds and fragments of marine shells have been encountered from time to time by various workers in the pre-Holocene coastal marine sands of Tasmania, the acid groundwater environment of most of the island does not favour good preservation. The few substantive faunal records obtained to date come from sites underlain by either limestones or dolerites and they are recorded here together with comments on their occurences. The collections have been catalogued and placed in the Tasmanian Museum and Art Gallery, Hobart, for future reference.

BROADMEADOWS

The molluscan fauna consisted of 51 species that were in a good state of preservation, some bearing their original surface colouring (table 1). They were recovered from a section in a drainage ditch located at grid reference 366731 (Tasmanian 1:100 000 Topographic Map Series, Sheet 7916, First Edition) where, beneath the surface peaty soil, there is more than one metre of marine fine sands overlying Precambrian dolomite. Fluctuations of the groundwater table in the upper 0.1-0.15 m of the sands had reduced the shells to moulds and had recemented the sands with carbonates, but below the permanent water table the shells were abundant and perfectly preserved. There were very few broken or wave-worn shells. The fauna occurs at 13 m above present high water mark and 6 km from the sea.

MONTAGU

Sixty-eight species of Mollusca were encountered in fine marine sands beneath the surface peaty soil in a pit dug at grid reference point 274829 (Sheet 7816, First Edition) (table 1). The shells were very well preserved and most bear their original surface colourings. As at Broadmeadows, the shell material in the surface 0.1 to 0.15 m has been reduced to moulds and the sands have been recemented with carbonate, but below the permament water table the shells are so well preserved that few are broken or strongly wave-worn. The marine sands are underlain by Tertiary limestones. The shells occur at 11 m above present high water mark and are 3 km from the sea.

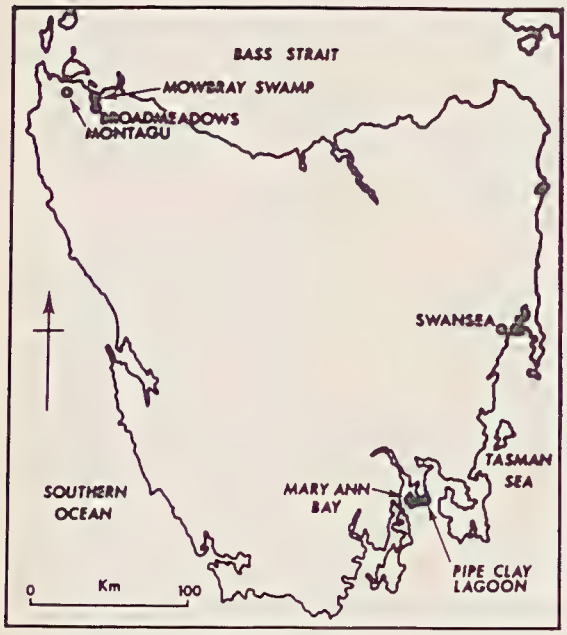

FIG. 1.- Locality map.

SWANSEA

Nine species of Mollusca were obtained from a pit dug in the bottom of a deep drainage ditch at grid reference 876393 (Sheet 8513, First Edition) and west of Wet Marsh Bridge 4 km north of Swansea (table 2). The shells occur 6.4 m above present high water mark and 3 km from the sea. They are enclosed within very stiff, waterlogged sandy clay which is sealed by more than a metre of black alluvial clay that forms the surface of the terrace at approximately 8 m above present high water mark. The underlying rock is Jurassic dolerite. The shells are well preserved but are delicate and break easily during extraction from the clay. Although the complete assemblage was recorded from this site, five species, *Austrocochlea constricta zebra*, *?Diala lauta*, *Ostrea angasi*, *Notospisula trigonella* and *Tellina deltoidalis* (table 2) were also encountered at another site east of Wet Marsh Bridge and 1 km nearer the sea (N.K. Chick and W. Cromer, pers. comm.).

MARY ANN BAY

From an open cliff section 49 molluscan species were obtained in fine to medium marine sands and silts at grid reference 322417 (Sheet 8312, First Edition) on the South Arm Peninsula at the mouth of the Derwent estuary (table 2). The marine deposits overlie a bench on top of the Jurassic dolerite cliffs and extend up to at least 22 m above present high water mark. Although sparse shell fragments can be found throughout the marine deposits, shells are only really abundant between 20 and 21 m above HWM and immediately beneath the surface soil profile. The shell beds dip gently seaward at 5-15°, towards the mouth of the Derwent. The shells are moderately well-preserved but some decalcification has taken place by soil forming processes which gives the shells a powdery surface appearance and free carbonate has been precipitated on the vertical joints. The surface of the marine deposits at 22 m above HWM is not original as it has been deflated by severe wind erosion subsequent to deposition (Colhoun 1975).

COMMENTS

These fossil molluscan faunas do not contain any extinct species and consist only of species living today in intertidal and shallow offshore areas of Tasmania (May 1923; Kershaw 1958). The fossil status of these assemblages is unequivocal. All occur either long distances inland or at considerable height above Holocene marine deposits, or both. The pre-last glacial age of the Broadmeadows and Montagu faunas is indicated by their occurrence within fine marine sands which are stratigraphically continuous with marine sands that occur beneath organic soils and swamp peats that have been radiocarbon dated to more than 52 000 years B.P. (GrN-9342) at Mowbray Swamp (van de Geer, in prep.). The pre-last glacial age (~25 000 to 10 000 B.P.) of the Swansea and Mary Ann Bay faunas is supported by the facts that the clay deposits of the former have been deflated to form a lunette dune, and the sands of the latter have been deflated to produce a 13 m deep

enclosed hollow. Such wind action in southeastern Tasmania with the development of dune landforms and erosion of deflation hollows has been radiocarbon dated to younger than 25 300 ± 640 years B.P. at Pipe Clay Lagoon (SUA-151) (Colhoun 1977). The faunas cannot be differentiated in age and their stratigraphic relationship with other sediments and landforms suggests that they are likely to belong to the period of interglacial high sea level that preceded the last glaciation, viz. the Last Interglacial.

Although the geomorphological environments are easily reconstructed there is very little detailed knowledge of the present ecology of Tasmanian Mollusca so that only a very general assessment of the palaeoenvironments is possible by ecological analogy. The shell assemblage at Broadmeadows is dominated by subtidal pelecypods; species that mainly occur in association with beach backwash deposits near low tide mark along the shores of open sandy embayments. This is consistent with the geomorphological evidence which indicates that a broad sandy marine embayment occurred in the area. In contrast, the Montagu fauna contains a greater number of species than the Broadmeadows fauna and includes more gastropods that prefer rock substrates to live on. The mixed character of the fauna with some species preferring sandy conditions and others rocky habitats indicates that the fossil environment of Montagu was probably that of a quiet sandy bay protected from strong wave action by intertidal and subtidal reefs, as occurs today off the far northwestern coastline.

The Swansea fauna is markedly different from any of the others and contains four species, *Austrocochlea constricta zebra*, *Clanculus dunkeri*, *Katelysia rhytiphora* and *Tellina deltoidalis* not found at the other sites. The abundance of small gastropods and their perfect preservation, in addition to the sandy clay texture of the deposits, indicates that they were deposited in the inner part of a shallow-water estuary. This estuary can be traced as a geomorphological feature that connects with the sea at Nine Mile Beach and the mouth of the Swan River.

The Mary Ann Bay shell deposit is dominated by *Pecten meridionalis* and approximately half the fauna consists of gastropods and half pelecypods. This indicates that the palaeoenvironment consisted of a variety of sandy/silty and rocky substrates similar to those available near the mouth of the Derwent estuary today. This interpretation is consistent with the geomorphological evidence for an outer estuarine environment during the Last Interglacial high sea level phase, which in Tasmania is believed to have attained a relative height of at least 21 m above present high water mark (van de Geer *et al.* 1979).

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TABLE 1

NORTHWESTERN TASMANIA

	Broadmeadows	Montagu
Haliotis ruber Leach, 1814		x
Amblychilepas nigrita (Sowerby, 1834)	x	
Hemitoma subemarginata (Blainville, 1819)		x
Patelloida profunda calamus (Crosse & Fischer, 1864)	x	
Austrocochlea concamerata (Wood, 1828)		x
Austrocochlea constricta (Lamarck, 1822)		x
Austrocochlea odontis (Wood, 1828)		x
Bankivia fasciata (Menke, 1830)		x
Calliostoma australe? (Broderip, 1835)		x
Clanculus limbatus (Quoy & Gaimard, 1834)		x
Clanculus plebejus (Philippi, 1851)		x
Phasianotrochus rutilis (A. Adams, 1851)		x
Thalotia conica (Gray, 1827)	x	x
Phasianella sp.	x	x
Turbo undulatus (Solander, 1786)		x
Eatoniella sp.	x	
Powellisetia simillima (May, 1915)	x	
Badepigrus badius (Petterd, 1884)	x	
Pisinna frenchiensis (Gatliff & Gabriel, 1908)	x	
Gazameda tasmanica (Reeve, 1849)		x
Serpulorbis sipho (Lamarck, 1818)		x
Zeacumantus diemenensis (Quoy & Gaimard, 1834)		x
Bittium granarium (Kiener, 1842)	x	
Hypotrochus monachus (Crosse & Fischer, 1864)	x	
Notosinister festiva? (A. Adams, 1851)	x	
Notosinister pfeifferi (Crosse & Fischer, 1865)	x	
Melanella sp.	x	
Agatha metcalfei (Pritchard & Gatliff, 1900)	x	
Chemnitzia mariae (Tenison Woods, 1876)	x	
Sigapatella calyptraeformis (Lamarck, 1822)	x	x
Zeacrypta immersa (Angas, 1865)		x
Ectosinum zonale (Quoy & Gaimard, 1833)		x
Polinices incei (Philippi, 1851)		x
Polinices conicus (Lamarck, 1822)	x?	x
Polinices sordidus (Swainson, 1821)		x
Polinices aulacoglossa (Pilsbry & Vanatta, 1908)		x
Eunaticina umbilicata (Quoy and Gaimard, 1900)		x
Notocypraea angustata (Gmelin, 1791)		x
Cymatiella verrucosa (Reeve, 1844)		x
Negyrina subdistorta (Lamarck, 1822)		x
Bedeva paivae (Crosse, 1864)	x	
Pterynotus triformis (Reeve, 1845)		x
Lepsiella vinosa (Lamarck, 1822)		x
Dentimitrella sp.		x
Macrozafra atkinsoni (Tenison Woods, 1875)	x	
Pseudamyela miltostoma? (Tenison Woods, 1876)	x	x
Cominella lineolata (Lamarck, 1809)		x
Penion maxima (Tryon, 1881)		x
Nassarius nigellus (Reeve, 1854)	x	
Nassarius pauperata (Lamarck, 1822)		x
Pleuroploca australasia (Perry, 1811)		x
Amalda petterdi (Tate, 1893)	x	
Cupidoliva nympha (Adams & Angas, 1863)		x
Amorena undulata (Lamarck, 1804)		x

	Broadmeadows	Montagu
Cancellaria sp. *C. spirata* Lamarck, 1822 or *C. lactea* Deshayes, 1832		x
C. granosa (Sowerby, 1832)		x
Sinuginella pygmaeoides (Singleton, 1937)		x
Epidirona quoyi (Reeve, 1843)		x
Guraleus pictus (Adams & Angas, 1863)	x	x
Mitraguraleus australis (A. Adams & Angas, 1863)		x
Pervicacia bicolor (Angas, 1867)		x
Acteocina sp.	x	
Retusa atkinsoni (Tenison Woods, 1875)	x	
Retusa sp.	x	
Retusa sp. + *Retusa* sp. nov.	x	
Salinator fragilis (Lamarck, 1822)		x
Siphonaria diemenensis Quoy & Gaimard, 1833		x
Cadulus vincentianus Cotton & Godfrey, 1940	x	
Glycymeris sp.	x	
Glycymeris striatularis (Lamarck, 1819)	x	x
Mytilus planulatus (Lamarck, 1819)		
Chlamys asperrima (Lamarck, 1819)	x	x
Pecten meridionalis Tate, 1886		x
Ostrea angasi Sowerby, 1871	x	x
Neotrigonia margaritacea (Lamarck, 1804)	x	x
Cuna concentrica Hedley, 1902	x	
Venericardia bimaculata (Deshayes, 1852)	x	x
Cyamiomactra mactroides (Tate & May, 1900)	x	
Divalucina cumingi (A. Adams & Angas, 1863)		x
Myrtea botanica Hedley, 1918	x	x
Wallucina assimilis (Angas, 1867)	x	
Bornia trigonale (Tate, 1879)	x	
Mysella donaciformis Angas, 1878	x	
Fulvia tenuicostata (Lamarck, 1819)	x	x
Notocallista diemenensis (Hanley, 1844)	x	x
Callanaitis disjecta (Perry, 1811)		x
Chioneryx cardioides (Lamarck, 1818)	x	x
Eumarica fumigata (Sowerby, 1853)	x	
Katelysia peronii (Lamarck, 1818)	x	x
Placamen placida (Philippi, 1844)	x	x
Tawera gallinula (Lamarck, 1818)	x	x
Irus distans (Lamarck, 1818)		x
Irus (Notopaphia) grisea (Lamarck, 1818)		x
Mesodesma erycinaea (Lamarck, 1818)	x	x
Gari livida Lamarck, 1818	x	
Pseudarcopagia botanica Hedley, 1917		x
Hiatella australis (Lamarck, 1818)		x
Panopea australis Soweeby, 1833		x
Myadora brevis (Sowerby, 1829)	x	x
Myadora complexa Iredale, 1924	x	
Myadora tasmanica Tenison Woods, 1875		x

? denotes uncertain identification

TABLE 2

EASTERN TASMANIA

	Swansea	Mary Ann Bay
Patellanax chapmani (Tenison Woods, 1876)		x
Notoacmea flammea (Quoy & Gaimard, 1834)		x
Patelloida profunda calamus (Crosse & Fischer, 1864)		x
Austrocochlea constricta zebra (Menke, 1829)	x	
Bankivia fasciata (Menke, 1830)		x
Clanculus dunkeri (Koch, 1843)	x	
Hydrococcus brazieri (Tenison Woods, 1876)		x
Microdiscula charopa (Tate, 1899)		x
Ctenocolpus australis (Lamarck, 1822)		x
Zeacumantus diemenensis (Quoy & Gaimard, 1834)	x	
Cacozeliana granaria (Kierner, 1842)		x
Diala lauta A. Adams, 1862	x	x
Seila albosutura (Tenison Woods, 1876)		x
Syrnola tincta Angas, 1871		x
Clypeola hedleyi (Smith, 1915)		x
Sigapatella calyptraeformis (Lamarck, 1822)		x
Zeacrypta immersa (Angas, 1965)		x
Notocochlis sp.		x
Polinices conicus (Lamarck, 1822)		x
Bedeva paivae (Crosse, 1864)		x
Benthoxystus petterdi (Crosse, 1870)		x
Cominella lineolata Lamarck, 1809		x
Dentimitrella spp.		x
Nassarius nigellus (Reeve, 1854)		x
Nassarius pauperata (Lamarck, 1822)		x
Fusus novaehollandiae Reeve, 1848		x
Pleuroploca australasia (Perry, 1811)		x
Guraleus alucinans (Sowerby, 1896)		x
Guraleus incrustus (Tenison Woods, 1876)		x
Leionucula obliqua (Lamarck, 1819)		x
Glycymeris sp.		x
Mytilus planulatus (Lamarck, 1819)		x
Chlamys asperrima (Lamarck, 1819)		x
Chlamys atkinos (Petterd, 1886)		x
Equichlamys bifrons (Lamarck, 1819)		x
Pecten meridionalis Tate, 1886		x
Ostrea angasi Sowerby, 1871	x	x
Cardita calyculata (Linné, 1758)		
Venericardia bimaculata (Deshayes, 1852)		x
Divalucina cumingi (A. Adams & Angas, 1863)		x
Lasaea australis (Lamarck, 1818)		x
Fulvia tenuicostata (Lamarck, 1819)	x	x
Notocallista kingi (Gray, 1827)		x
Chioneryx cardioides (Lamarck, 1818)		x
Katelysia rhytiphora Lamy, 1937	x	
Katelysia sp.		x
Placamen placida (Philippi, 1844)		x
Tawera gallinula (Lamarck, 1818)		x
Mesodesma erycinaea (Lamarck, 1818)		x
Mactra jacksonensis (Smith, 1885)		x
Notospisula trigonella (Lamarck, 1818)	x	x
Gari livida (Lamarck, 1818)		x
Tellina albinella Lamarck, 1818		x
Tellina deltoidalis Lamarck, 1818	x	x

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THE BRYOPHYTES OF THE MT WELLINGTON RANGE, TASMANIA

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(with five tables)

ABSTRACT

RATKOWSKY, D.A. and A.V., 1982 (31 viii): The bryophytes of the Mt Wellington Range, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 97-115. ISSN 0080-4703. C.S.I.R.O., Hobart, Tasmania.

A census of the bryophyte flora of the Mt Wellington Range, Tasmania, is reported, the field work having been carried out between 1 May 1977 and 31 October 1980. The survey area was similar in extent to that used by the authors in an earlier survey of the vascular plants. A total of 164 mosses and 130 liverworts was found in the survey area, representing more than 60% of the known Tasmanian bryophyte flora, including several species not previously known to occur in Tasmania. The number of moss species was greatest at middle and lower altitudes whereas the number of liverwort species was greatest at middle and higher altitudes. Reports of liverwort species in this census are accompanied by references to works containing descriptions and drawings, wherever possible, of these species. Only a few species known from past information or collections to have occurred on Mt Wellington were missing in the current survey despite the devastating bushfire of 7 February 1967.

INTRODUCTION

Serious efforts were made to study the bryophyte flora of Tasmania before that of most other parts of Australia. Bastow (1886-87) published a four-part paper (with an illustrated fold-out key) on the Tasmanian mosses and within thirty years Rodway (1913-14) brought out an extensive revision. Similarly, Bastow (1888) published an illustrated account of the Tasmanian liverworts, and Rodway (1917) provided an extensive revision. Although Rodway recognized that many of his "species" were really different forms of the same species and therefore not fully deserving of specific rank, it was only relatively recently that bryologists have brought into synonymy many of these forms previously considered to be distinct. Indeed, the plasticity of many species both in their vegetative and reproductive organs is probably at least as great as in the flowering plants, and perhaps bryologists of the future will increase the list of synonyms still further. Since Rodway's time many genuine new species have been added to the bryophyte flora of Australasia (including Tasmania) due to the efforts of such workers as H.N. Dixon, G.O.K. Sainsbury, J.H. Willis, E.A. Hodgson, K.W. Allison, R. Grolle and R.M. Schuster.

SURVEY AREA AND VEGETATION ZONES

The field work for the present survey was carried out between 1 May 1977 and 31 October 1980, the survey area used being the same as that employed for a census of the vascular plants of the Mt Wellington Range (Ratkowsky & Ratkowsky 1976). Details of the vegetation zones occurring within the survey area are given in that paper and will not be repeated here, although Table 1 summarizes the main features and approximate elevations of each zone. Unlike the earlier survey where a minimum elevation of 240 m was employed in order to make a comparison with a previously published survey, no lower elevation limit was used in the present survey, except that bryophytes growing in the vicinity of habitation were not included.

CENSUS OF THE MOSSES

An important publication subsequent to the revision of the moss flora by Rodway (1913-14) was the eight-part commentary of Sainsbury (1953-56) on the moss species in

TABLE 1

SUMMARY OF THE VEGETATION ZONES OF THE MT WELLINGTON RANGE

Zone	Description	Approximate elevation
1	Treeless upper regions.	1220-1270 m
2	Woodlands containing pure stands of *Eucalyptus coccifera*, and treeless marshlands and grasslands at the same elevations.	1100-1220 m
3a	Woodlands with mixed eucalypt stands, dominant eucalypt *E. urnigera*, and treeless marshlands and grasslands at the same elevations.	800-1100 m
3b	Wet sclerophyll forests, dominant eucalypt *E. delegatensis*.	600- 800 m
4	Wet sclerophyll forests, dominant eucalypt *E. obliqua*.	Below 670 m
5	Sandstone outcrops such as Snake Plains, The Springs, Sphinx Rock, etc., dominant eucalypt *E. johnstonii*.	600- 750 m
6	Gully communities, permanently wet, with thick undergrowth of *Bedfordia salicina* and *Olearia argophylla*.	Below 600 m
7	Dry sclerophyll open forests, dominant eucalypts *E. pulchella* and *E. viminalis* (on dolerite) or *E. tenuiramis* (on mudstone).	Below 500 m

what was then Rodway's herbarium (now incorporated into the Tasmanian Herbarium). These papers, together with the works of J.H. Willis, and others, helped form the basis for the moss flora of southern Australia of Scott and Stone (1976). Their treatment must now be the starting point for any serious revision of the moss flora of this region. The ordering of the families and genera in the present census (Table 2) follows Scott and Stone (1976), and the names of species, arranged alphabetically, adhere to those given in that work, except where more recent knowledge requires modification. Footnotes, which are listed at the end of table 2, are used for clarification, to impart extra information, or to indicate unsolved problems of taxonomic interest.

Mosses are notoriously difficult to identify with certainty in the field, as the identity of many species can usually only be determined with confidence after microscopic examination. This fact makes it difficult to accurately assess the abundance of a species in a vegetation zone. Thus, unlike the census of vascular plants (Ratkowsky & Ratkowsky 1976), no assessment of the frequency of occurrence of a species is indicated in table 2, presence in any zone being indicated by a "x". However, where a species was found only once during the survey, its occurrence is indicated by a "r" to signify that it is rare.

CENSUS OF THE LIVERWORTS

Discussion of a census of Tasmanian liverworts is complicated by the absence of a modern treatment of the hepatic flora of this region, as there is as yet no comprehensive work on liverworts equivalent to that of Scott and Stone (1976) on the mosses. There are a number of large families, notably those of Lophocolaceae and Lepidoziaceae, that are badly in need of revision. The lack of an equivalent to Scott and Stone (1976) has prompted a different approach to the presentation of the census of the liverworts of Mt Wellington in table 3. Each species listed is followed by a number indicating a footnote. The footnotes appear at the end of the table and provide references to literature either citing nomenclature or providing descriptions and illustrations, wherever possible,

TABLE 2

THE MOSSES OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
Sphagnaceae								
Sphnagnum australe Mitt.			x			x		
S. cristatum Hampe	x	x	x			x		
S. falcatulum Besch.	x	x						
S. subsecundum (1) Nees	x	x	x			x		
Andreaeaceae								
Andreaea rupestris (2) Hedw.	x	x	x	x				x
A. subulata Harv. ex Hook.				r				
Polytrichaceae								
Polytrichum alpinum Hedw.	x	x						
P. commune Hedw.	x	x	x	x		x	x	
P. juniperinum Hedw.	x	x	x	x	x	x	x	x
Atrichum androgynum (C. Muell.) Jaeg.					x		x	
Pogonatum subulatum (Brid.) Brid.				x	x		x	
Polytrichadelphus magellanicus (Hedw.) Mitt.		x		x	x	x	x	
Psilopilum australe (Hook.f. & Wils.) Mitt.	x	x	x					
P. crispulum (Hook.f. & Wils.) Mitt.		x	x					
Fissidentaceae								
Fissidens asplenioides Hedw.								x
F. dealbatus Hook.f. & Wils.							r	
F. leptocladus C. Muell. & Rodw.					x	x	x	x
F. pallidus Hook.f. & Wils.					x			
F. pungens C. Muell. & Hampe			x	x	x	x	x	x
F. rigidulus Hook.f. & Wils.				x	x	x	x	x
F. taylorii C. Muell.				x	x		x	x
F. tenellus Hook.f. & Wils.					x	x	x	x
F. vittatus Hook.f. & Wils.							x	x
Grimmiaceae								
Grimmia apocarpa (Hedw.) B.S.G.				x	x	x		x
G. laevigata (Brid.) Brid.								r
G. pulvinata (Hedw.) Sm.								x
G. trichophylla Grev.	x	x	x	x	x	x	x	
Rhacomitrium crispulum (Hook.f. & Wils.) Dix.	x	x	x	x	x	x	x	x
R. lanuginosum (Hedw.) Brid. var. *pruinosum* Wils.	x	x	x	x				
Ditrichaceae								
Ditrichum cylindricarpum (C. Muell.) F. Muell.					x		x	
D. difficile (Dub.) Fleisch.				x	x	x	x	x
D. punctulatum Mitt.	x	x	x	x	x	x	x	
Ceratodon purpureus (Hedw.) Brid.	x	x	x	x	x	x	x	x
Eccremidium pulchellum (Hook.f. & Wils.) C. Muell.								x
Cheilothela chilensis (3) (Mont.) Broth.	x	x	x					
Seligeriaceae								
Blindia magellanica Schimp.				x	x		x	
B. robusta Hampe	x	x						
B. tasmanica Sainsb.						r		
Dicranaceae								
Campylopus clavatus (R.Br.) Wils.	x	x	x	x	x	x		x
C. introflexus (Hedw.) Brid.	x	x	x	x	x	x	x	x
C. pallidus Hook.f. & Wils.			x	x	x	x	x	
Dicranella cardotii (R.Br. ter.) Dix.				x	x			
D. dietrichiae (4) (C. Muell.) Jaeg.						r		
Dicranoloma billardieri (Brid.) Par.	x	x	x	x	x	x	x	x
D. dicarpum (Nees) Par.					x		x	
D. menziesii (Tayl.) Par.					x		x	

TABLE 2 (CONT.)

THE MOSSES OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
Dicranoweisia microcarpa (Hook.f. & Wils.) Par.	x	x	x	x	x			x
Leucobryum candidum (P. Beauv.) Wils.							x	
Pottiaceae								
Acaulon integrifolium C. Muell.					x			
Calyptopogon mnioides (Schwaegr.) Broth.					x		x	
Tortula muralis Hedw.	x	x	x	x	x	x	x	x
T. papillosa Wils.					x			x
T. princeps De Not.		x	x		x			x
T. rubra (5) Mitt.		r						
Gymnostomum calcareum Nees & Hornsch.						x	x	x
Tortella calycina (Schwaegr.) Dix.		x	x	x	x		x	x
T. knightii (Mitt.) Broth.		x	x	x	x			
Tridontium tasmanicum Hook.f.								x
Weissia controversa Hedw.			x	x	x	x		
Barbula australasiae (Hook. & Grev.) Brid.					x		x	x
B. crinita (6) Schultz					x	x		x
B. torquata Tayl.					x	x		x
B. unguiculata Hedw.								x
Bryoerythrophyllum jamesonii (7) (Tayl.) Crum				x	x		x	x
Triquetrella papillata (Hook.f. & Wils.) Broth.					x			x
Anomodon tasmanicus (8) Broth.								x
Encalyptaceae								
Encalypta vulgaris Hedw.						x		x
Orthotrichaceae								
Orthotrichum tasmanicum Hook.f. & Wils.					x		x	
Macromitrium archeri Mitt.					x		x	x
M. weymouthii Broth.							r	
Ulota lutea (9) (Hook.f. & Wils.) Mitt.				r				
Zygodon hookeri Hampe							r	
Z. intermedius B.S.G.	x	x	x	x	x	x	x	x
Z. menziesii (Schwaegr.) Arnott					x		x	x
Funariaceae								
Funaria apophysata (Tayl.) Broth.		r						
F. glabra Tayl.					x		x	x
F. gracilis (Hook.f. & Wils.) Broth.					x			x
F. hygrometrica Hedw.		x	x	x	x		x	x
F. producta (Mitt.) Broth.								r
Splachnaceae								
Tayloria octoblepharis (Hook.) Mitt.	x	x	x	x	x			x
Bryaceae								
Bryum argenteum Hedw.	x	x	x	x	x	x		x
B. billardieri Schwaegr.		x	x	x	x	x	x	x
B. blandum Hook.f. & Wils.				x	x		x	
B. capillare Hedw.	x	x	x	x	x	x	x	x
B. crassum Hook.f. & Wils.		r						
B. dichotomum Hedw.	x	x	x	x	x	x		x
B. erythrocarpoides C. Muell. & Hampe				x			x	x
B. laevigatum Hook.f. & Wils.		x	x	x	x	x	x	
B. micro-erythrocarpum C. Muell. & Kindb.								r
B. pachytheca C. Muell.						x		x
B. pseudotriquetrum (Hedw.) Gaertn., Meyer & Scherb.			x		x			
Leptostomum inclinans R.Br.			x	x	x		x	x
Mielichhoferia bryoides (Harv.) Wijk & Marg.				x	x	x		

TABLE 2 (CONT.)

THE MOSSES OF THE MT WELLINGTON RANGE

	Zone 1	2	3a	3b	4	5	6	7
Orthodontium lineare Schwaegr.				x	x	x	x	x
Pohlia cruda (Hedw.) Lindb.	x	x	x	x				
P. nutans (Hedw.) Lindb.		x	x	x	x	x	x	x
Aulacomniaceae								
Leptotheca gaudichaudii Schwaegr.	x	x	x	x	x	x	x	
Mitteniaceae								
Mittenia plumula (Mitt.) Lindb.	x	x	x	x	x		x	
Rhizogoniaceae								
Rhizogonium bifarium (Hook.) Schimp.							x	
R. distichum (Sw.) Brid.					x		x	
R. mnioides (Hook.) Wils.		x	x	x	x	x	x	
R. novae-hollandiae (Brid.) Brid.		x		x			x	
Goniobryum subbasilare (Hook.) Lindb.					x		x	
Hymenodon pilifer Hook.f. & Wils.							x	
Bartramiaceae								
Bartramia hallerana Hedw.				x	x		x	x
B. cf. hampeana C. Muell.								x
B. papillata Hook.f. & Wils.	x	x	x	x	x	x		x
Bartramidula pusilla (Hook.f. & Wils.) Par.								x
Breutelia affinus (Hook.) Mitt.	x	x	x	x	x	x	x	x
B. elongata (Hook.f. & Wils.) Mitt.	x	x	x	x	x	x	x	x
B. pendula (Sm.) Mitt.	x		x	x	x	x	x	x
Conostomum pentastichum (Brid.) Lindb.	x	x	x					
C. pusillum Hook.f. & Wils.	x	x	x			x		x
Philonotis scabrifolia (Hook.f. & Wils.) Braithw.	x	x	x	x	x		x	
P. tenuis (Tayl.) Reichdt.		x	x	x	x	x	x	x
Hypnodendraceae								
Hypnodendron comosum (Labill.) Mitt.							x	
H. spininervium (Hook.) Jaeg.					x		x	
H. vitiense Mitt.					x		x	
Rhacopilaceae								
Rhacopilum convolutaceum (C. Muell.) Reichdt.				x	x		x	x
Hedwigiaceae								
Hedwigia ciliata (Hedw.) Ehrh.		x	x	x	x	x		x
H. integrifolia P. Beauv.				x	x	x		x
Rhacocarpus purpurascens (Brid.) Par.	x	x	x					
Ptychomniaceae								
Ptychomnion aciculare (Brid.) Mitt.				x	x	x	x	x
Glyphothecium sciuroides (Hook.) Hampe							r	
Lepyrodontaceae								
Lepyrodon lagurus (Hook.) Mitt.	x	x	x					
Meteoriaceae								
Weymouthia cochlearifolia (Schwaegr.) Dix.					x		x	
W. mollis (Hedw.) Broth.							r	
Neckeraceae								
Thamnobryum pumilum (Hook.f. & Wils.) Nieuwl.					x		x	
Echinodiaceae								
Echinodium hispidum (Hook.f. & Wils.) Reichdt.					x		x	
Lembophyllaceae								
Lembophyllum divulsum (Hook.f. & Wils.) Par.		x	x	x	x		x	x
Camptochaete arbuscula (Sm.) Reichdt.					x		x	x
C. gracilis (Hook.f. & Wils.) Par.		x	x	x	x		x	

TABLE 2 (CONT.)

THE MOSSES OF THE MT WELLINGTON RANGE

	Zone 1	2	3a	3b	4	5	6	7
Hookeriaceae								
Distichophyllum microcarpum (Hedw.) Mitt.				x	x		x	
D. pulchellum (Hampe) Mitt.		x	x	x			x	
Eriopus apiculatus (Hook.f. & Wils.) Mitt.							x	
Acrophyllum dentatum (10) (Hook.f. & Wils.) Vitt & Crosby	x	x	x	x	x		x	x
Sauloma tenella (Hook.f. & Wils.) Mitt.					x		x	
Hypopterygiaceae								
Hypopterygium rotulatum (Hedw.) Brid.		x	x	x	x		x	x
Cyathophorum bulbosum (Hedw.) C. Muell.					x		x	
Lopidium concinnum (Hook.) Wils.							x	
Thuidiaceae								
Thuidium furfurosum (11) (Hook.f. & Wils.) Reichdt.			x	x	x	x	x	x
Amblystegiaceae								
Acrocladium chlamydophyllum (Hook.f. & Wils.) C. Muell. & Broth.				x	x	x	x	x
A. cuspidatum (Hedw.) Lindb.				x	x	x	x	x
Cratoneuropsis relaxa (Hook.f. & Wils.) Fleisch.							r	
Brachytheciaceae								
Brachythecium albicans (Hedw.) B.S.G.					x	x		x
B. paradoxum (Hook.f. & Wils.) Jaeg.	x	x				x		
B. rutabulum (Hedw.) B.S.G.				x	x	x	x	x
B. salebrosum (Web. & Mohr) B.S.G.				x	x	x		
Eurhynchium asperipes (Mitt.) Dix.							r	
E. austrinum (Hook.f. & Wils.) Jaeg.					x		x	x
E. muriculatum (Hook.f. & Wils.) Jaeg.				x	x		x	
E. praelongum (Hedw.) B.S.G.					x	x	x	x
Pseudoscleropodium purum (12) (Hedw.) Fleisch.					x			
Rhynchostegium sp. (13)					x		x	x
Fabroniaceae								
Fabronia australis Hook.					r			
Plagiotheciaceae								
Plagiothecium denticulatum (Hedw.) B.S.G.	x	x	x		x		x	
Catagonium politum (Hook.f. & Wils.) Dus.	x	x	x	x	x		x	
Isopterygium limatum (Hook.f. & Wils.) Broth.	x	x	x	x	x	x	x	x
Sematophyllaceae								
Sematophyllum amoenum (Hedw.) Mitt.				x	x	x	x	x
S. homomallum (Hampe) Broth.							x	
S. leucocytus (C. Muell.) Sainsb.				x	x		x	x
S. uncinatum Stone & Scott				x	x		x	
Wijkia extenuata (Brid.) Crum				x	x		x	x
Hypnaceae								
Hypnum chrysogaster (14) C. Muell.			x		x	x	x	
H. cupressiforme Hedw.	x	x	x	x	x	x	x	x

Footnotes (all references to Scott & Stone 1976, are abbreviated S&S).

(1) This may really be *S. cymbifolioides* C. Muell. (see S&S p.453).

(2) Vitt (1980) showed that *A. rupestris* does not occur in the Southern Hemisphere and that material previously referred to by this name is mostly *A. mutabilis*.

(3) This species is not given as occurring in Tasmania by S&S p.454.

(4) This species is not given as occurring in Tasmania by S&S p.148, but we have also found it in Hartz Mtn National Park.

TABLE 2 (CONT.)

THE MOSSES OF THE MT WELLINGTON RANGE

(5) *Tortula rubra*, found at Trestle Mtn, is a new Tasmanian record; we have also found it in Ben Lomond and Cradle Mountain National Parks.
(6) This name, as noted by S&S p.454, replaces *Barbula pseudopilifera* C. Muell. & Hampe.
(7) This species is listed in S&S P.215 as *B. binnsii* (R.Br.ter.) Wijk & Marg. (see Ratkowsky 1980b, p.367).
(8) This species was found at Knocklofty, Tolmans Hill, Browns River, Ridgeway Reservoir, etc. but sporophytes were not seen and its taxonomic position remains uncertain (see S&S p.218).
(9) According to Malta (1933), several species of *Ulota* occur on Mt Wellington, which are supposedly easy to distinguish using vegetative characters.
(10) This name now replaces *Pterygophyllum dentatum* (Hook.f. & Wils.) Dix. (see S&S p.454).
(11) Forms both with single and multiple cell papillae have been found. We believe the drawings in S&S on p.403 and p.405, the latter purporting to be of *T. laeviusculum* (Mitt.) Jaeg., are of different forms of a single species.
(12) This species, found near a creek behind the Cascade Brewery and also near Strickland Avenue, is a new record for Tasmania.
(13) The Mt Wellington material appears to be *Rhynchostegium laxatum* (Mitt.) Par. rather than *R. tenuifolium* (Hedw.) Reichdt., but as noted by S&S p.431, a thorough revision of these two species is needed.
(14) The orange-to-yellow inflated alar cells seem to distinguish this species from *Hypnum cupressiforme* Hedw.

of the species. For example, Allison and Child (1975), wherever it is cited, contains a brief description and a drawing of the relevant species.

The ordering of the families and of the five hepatic orders follows the proposal of Grolle (1972) with slight alterations, the taxonomic arrangement of the families within orders being alphabetic. Similarly, genera within families, and species within genera, are listed alphabetically. As with the mosses in table 2, presence of a species in a zone is indicated in table 3 by a "x" or a "r" (if it was found only once in the survey).

DISCUSSION

Rodway (1913-14, 17) listed a very high proportion of Tasmanian bryophytes as occurring on Mt Wellington, indicating the prominent place that this mountain has held in Tasmanian bryology. In our earlier survey of the vascular plants (Ratkowsky & Ratkowsky 1976) it was found that more than one-third of the known flowering plants of Tasmania occurred on Mt Wellington. In the present census, 164 moss species and 130 liverwort species are reported, representing more than 60% of the approximately 270 known Tasmanian moss species and the approximately 210 known Tasmanian liverwort species. This reaffirms the importance of this mountain range as a significant natural reserve of representative Tasmanian vegetation.

This census has revealed several species that were previously unknown in Tasmania. Two moss species, *Tortula rubra* and *Pseudoscleropodium purum*, are new records for Tasmania, at least in the sense that they are not given by Scott and Stone (1976) as occurring in Tasmania. *Cheilothela chilensis* is also omitted from Scott and Stone (1976), but we have also found it at Mt Field National Park. This distinctive plant, also known from South America, New Zealand, Victoria and New South Wales, but not common in any of those places, is now rather widespread as a colonizer of open ground at the higher elevations of Mt Wellington. No sporophytes have been found in Tasmanian material.

TABLE 3

THE LIVERWORTS OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
Order A: Anthocerotales								
Anthocerotaceae								
Megaceros sp. (1)				x	x		x	
Phaeoceros sp. (2)			x	x	x			
Order B: Marchantiales								
Aytoniaceae								
Asterella drummondii (Tayl.) Schust. (3)								r
Lunulariaceae								
Lunularia cruciata (L.) Dum. (4)			x		x		x	x
Marchantiaceae								
Marchantia berteroana Lehm. & Lindenb. (5)	x	x	x	x	x	x	x	
M. foliacea Mitt. (6)				x	x		x	
Ricciaceae								
Riccia sp. (7)								r
Order C: Metzgeriales								
Aneuraceae								
Aneura alterniloba (Hook.f. & Tayl.) Tayl. (8)		x	x	x	x		x	x
A. rodwayi Hewson (9)		r						
Riccardia aequicellularis (Steph.) Hewson (10)	x	x	x	x	x	x	x	x
R. alcicornis (Hook.f. & Tayl.) Trev. (11)		r						
R. cochleata (Hook.f. & Tayl.) Kuntze (12)				x	x		x	
R. colensoi (Steph.) Martin (13)			x	x	x		x	
R. crassa (Schwaegr.) Carringt. & Pears. (14)	x	x	x	x	x	x	x	x
R. longiflora (Steph.) Hewson (15)		x	x	x	x		x	
R. minima Carringt. & Pears. (16)							x	
R. rupicola (Steph.) Hewson (17)				x	x		x	
R. wattsiana (Steph.) Hewson (18)				x	x		x	
Codoniaceae								
Fossombronia pusilla (L.) Nees (19)		x	x	x	x	x		x
Hymenophytaceae								
Hymenophyton flabellatum (Labill.) Dum. ex Trev. (20)			x				x	
Metzgeriaceae								
M. atrichoneura Spruce (21)		r						
M. colensoi Steph. (22)							r	
M. densiseta Steph. (23)		x						
M. furcata (L.) Dum. (24)		x			x		x	x
M. leptoneura Spruce (25)				x	x		x	
M. saccata Mitt. (26)							r	
Pallaviciniaceae								
Pallavicinia xiphoides (Hook.f. & Tayl.) Trev. (27)			r					
Podomitrium phyllanthus (Hook.) Mitt. (28)							x	
Symphyogyna podophylla (Thunb.) Mont. & Nees (29)		x	x	x	x	x	x	x
Treubiaceae								
Treubia lacunosa (Col.) Prosk. (30)				r				
T. tasmanica Schust. & Scott (31)					r			
Order D: Calobryales								
Haplomitriaceae								
Haplomitrium gibbsiae (Steph.) Schust. (32)						r		

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
Order E: Jungermanniales								
Acrobolbaceae								
Acrobolbus cinerascens (Lehm. & Lindenb.) Bast. (33)		x	x				x	
Goebelobryum unguiculatum (Hook.f. & Tayl.) Grolle (34)		x	x		x	x		
Lethocolea squamata (Tayl.) Hodgs. (35)		x	x	x	x			
Tylimanthus pseudosaccatus Grolle (36)					x		x	
T. tenellus (Tayl. ex Lehm.) Mitt. (37)		x	x	x	x		x	
Adelanthaceae								
Adelanthus falcatus (Hook.) Mitt. (38)	x	x	x	x				
Balantiopsaceae								
Balantiopsis diplophylla (Hook.f. & Tayl.) Mitt. (39)	x	x	x	x	x		x	
B. tumida Berggr. (40)	x	x	x					
Isotachis intortifolia (Hook.f. & Tayl.) Gott. (41)	x	x	x	x	x	x	x	
Neesioscyphus phoenicorhizus Grolle (42)		x	x					
Cephaloziellaceae								
Cephaloziella exiliflora (Tayl.) Steph. (43)	x	x	x	x	x	x	x	x
C. hirta (?) (Steph.) Schust. (44)			x		x	x		
Chaetophyllopsidaceae								
Chaetophyllopsis whiteleggei (Carringt. & Pears.) Schust. (45)								r
Gymnomitriaceae								
Gymnomitrion incompletum (Gott.) Schust. (46)	x	x						
Herzogobryum aterrimum (Steph.) Grolle (47)	x							
H. erosum (Carringt. & Pears.) Grolle (48)	x	x						
H. teres (Carringt. & Pears.) Grolle (49)	x	x	x					
Herbertaceae								
Herbertus oldfieldianus (Steph.) Rodway (50)	x	x	x					
Triandrophyllum subtrifidum (Hook.f. & Tayl.) Fulf. & Hatch. (51)	x	x	x					
Jubulaceae								
Frullania clavata (Hook.f. & Tayl.) Tayl. (52)					x		x	
F. falciloba (Hook.f. & Tayl.) Lehm. (53)			x	x	x		x	x
F. monocera (Hook.f. & Tayl.) Tayl. (54)					x		x	
F. probosciphora Tayl. (55)					x		x	x
F. rostrata (Hook.f. & Tayl.) Hook.f. & Tayl. (56)				x	x			x
F. scandens Mont. (57)					x		x	
Jungermanniaceae								
Anastrophyllum schismoides (Mont.) Steph. (58)	x	x						
Andrewsianthus perigonialis (Hook.f. & Tayl.) Schust. (59)	x	x	x					
Cryptochila grandiflora (Lindenb. & Gott.) Grolle (60)	x	x	x					
Cuspidatula monodon (Hook.f. & Tayl.) Steph. (61)					x	x	x	
Jamesoniella colorata (Lehm.) Schiffn. (62)		x	x	x				x
J. tasmanica (Hook.f. & Tayl.) Steph. (63)					x		x	x
Jungermannia inundata Hook.f. & Tayl. (64)	x	x	x	x	x	x		
J. orbiculata (Col.) Grolle (65)	x	x	x			x		
Lophozia tasmanica Schust. (66)	x	x	x			x		

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
Lejeuneaceae								
Cheilolejeunea albo-virens (Hook.f. & Tayl.) Hodgs. (67)		r						
C. mimosa (Hook.f. & Tayl.) Schust. (68)					x		x	
Diplasiolejeunea plicatiloba (Hook.f. & Tayl.) Grolle (69)					r			
Harpalejeunea latitans (Hook.f. & Tayl.) Grolle (70)					x		x	
Lejeunea drummondii Tayl. (71)					x		x	
Lepicoleaceae								
Lepicolea scolopendra (Hook.) Dum. ex Trev. (72)		x	x	x				
Lepidolaenaceae								
Gackstroemia weindorferi (Herz.) Grolle (73)		x	x		x		x	x
Lepidolaena brachyclada (Tayl. ex Lehm.) Trev. (74)		x	x					
L. reticulata (Hook.f. & Tayl.) Trev. (75)		r						
Lepidoziaceae								
Acromastigum colensoanum (Mitt.) Evans (76)							x	
Bazzania adnexa (Lehm. & Lindenb.) Trev. (77)				x	x		x	
B. monilinervis (Lehm. & Lindenb.) Trev. (78)						r		
Hygrolembidium acrocladum (Berggr.) Schust. (79)	x	x	x					
H. australe (Steph.) Grolle (80)	r							
Kurzia hippuroides (Hook.f. & Tayl.) Grolle (81)	x	x	x	x	x	x	x	x
K. tenax (Grev.) Grolle (82)							x	
Lepidozia glaucophylla (Hook.f. & Tayl.) Tayl. (83)					x		x	
L. laevifolia (Hook.f. & Tayl.) Tayl. (84)		x		x	x		x	
L. pendulina (Hook.) Lindenb. (85)	x	x	x		x		x	x
L. ulothrix (Schwaegr.) Lindenb. (86)				x	x	x	x	x
Telaranea centipes (Tayl.) Schust. (87)					x	x		
T. gottscheana (Lindenb.) Hodgs. (88)				x	x	x	x	x
Zoopsis argentea (Hook.f. & Tayl.) Hook.f. (89)					x		x	
Z. leitgebiana (Carringt. & Pears.) Bast. (90)	x	x	x	x	x	x	x	
Lophocoleaceae								
Chiloscyphus allodontus (Hook.f. & Tayl.) Hodgs. (91)						r		
C. billardieri (Schwaegr.) Nees (92)		r						
C. coalitus (Hook.) Nees (93)		x	x	x	x		x	x
C. echinellus (Lindenb. & Gott.) Mitt. (94)							x	
C. fissistipus (Hook.f. & Tayl.) Tayl. (95)		x			x		x	x
C. kirkii Steph. (96)		x						
C. limosus Carringt. & Pears. (97)			x	x	x		x	
C. triacanthus (Hook.f. & Tayl.) Steph. (98)				x				
C. tridentatus Mitt. (99)		x	x	x	x			
Clasmatocolea marginata (Steph.) Grolle (100)		r						
C. strongylophylla (Hook.f. & Tayl.) Grolle (101)		x	x	x				
Hepatostolonophora paucistipula (Rodw.) Engel (102)		x	x					
H. rotata (Hook.f. & Tayl.) Engel (103)				r				
Leptophyllopsis laxus (Mitt.) Schust. (104)		x	x	x	x		x	
Leptoscyphus sp. (105)		x	x	x	x			
Lophocolea bidentata (L.) Dum. (106)		x	x	x	x			
L. excipulata Steph. (107)	r							
L. gunniana Nees (108)	x	x				x		

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

	Zone							
	1	2	3a	3b	4	5	6	7
L. lenta (Hook.f. & Tayl.) Tayl. (109)	x	x	x	x	x	x	x	x
L. leucophylla (Hook.f. & Tayl.) Tayl. (110)		x	x				x	
L. muricata (Lehm.) Nees (111)				x	x		x	
L. semiteres (Lehm.) Mitt. (112)			x	x	x	x	x	x
Plagiochilaceae								
Plagiochila baileyana Steph. (113)			x				x	
P. circinalis (Lehm. & Lindenb.) Lehm. & Lindenb. (114)		x	x					
P. fasciculata Lindenb. (115)	x	x			x		x	
P. incurvicolla (Hook.f. & Tayl.) Hook.f. & Tayl. (116)		x	x	x	x			
P. pleurata (Hook.f. & Tayl.) Hook.f. & Tayl. (117)		x	x					
P. radiculosa Mitt. (118)			r					
P. ratkowskiana H. Inoue (119)	x	x	x					
P. retrospectans (Nees) Nees (120)		x	x	x	x		x	x
P. strombifolia (Tayl.) Hook.f. & Tayl. (121)			x		x		x	x
Pseudolepicoleaceae								
Isophyllaria attenuata (Rodw.) Hodgs. (122)	x	x						
Temnoma townrowii Schust. (123)		x	x	x	x	x	x	x
Radulaceae								
Radula buccinifera (Hook.f. & Tayl.) Tayl. (124)	x	x	x	x	x		x	x
Radula sp. (125)	x	x			x		x	
Scapaniaceae								
Diplophyllum domesticum (Gott.) Steph. (126)	x	x	x					
Schistochilaceae								
Schistochila ciliata (Mitt.) Steph. (127)		r						
S. lehmanniana (Lindenb.) Carringt. & Pears. (128)			x	x	x		x	
Trichocoleaceae								
Trichocolea mollissima (Hook.f. & Tayl.) Gott. (129)							r	
T. rigida Schust. (130)				x	x		x	

Footnotes

(1) Carrington & Pearson 1888, pp.11-12; Bastow 1888, p.283, plates XXXV and XLIII, both as *Anthoceros longispirus*. Spores greenish, minutely verruculose; elators with a single, spiral band.

(2) Bastow 1888, p.283, plate XXXV as *Anthoceros laevis*; Allison & Child 1975, pp.283-284. Spores yellowish, papillose; elators rudimentary, lacking spiral bands.

(3) Bastow 1883, p.282; Rodway 1917, pp.57-58, both as *Fimbriaria drummondii*.

(4) Campbell 1965a, pp.31-42, figs.1-21; Allison & Child 1975, pp.271-273.

(5) Campbell 1965b, pp.122-126, figs.1-10; Allison & Child 1975, pp.272-277.

(6) Campbell 1965b, pp.126-130, figs.11-24; Allison & Child 1975, pp.274-278.

(7) The Australian species of the genus *Riccia* have recently been revised by Na-Thalang 1980. Tasmanian material was not studied, however.

(8) Hewson 1970a, pp.186-188, figs.1,3-4.

(9) Hewson 1970a, pp.188-189, figs.1,4; Allison & Child 1975, pp.252-253.

(10) Hewson 1970b, pp.79-80, fig.6.

(11) Hewson 1970b, p.77, fig.6.

(12) Hewson 1970b, pp.89-91, fig.8; Allison & Child 1975, pp.254-255.

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

(13) Hewson 1970b, pp.103-104, fig.11.
(14) Hewson 1970b, pp.104-106, fig.11.
(15) Hewson 1970b, pp.88-89, fig.8.
(16) Hewson 1970b, p.84, fig.7.
(17) Hewson 1970b, pp.99-100, fig.10.
(18) Hewson 1970b, pp.91-92, fig.9.
(19) Allison & Child 1975, pp.233-234. The genus is a very difficult one and is badly in need of revision; some of the Mt Wellington material may be other species of *Fossombronia*.
(20) Campbell *et al.* 1975, pp.593-600, fig.3; Allison & Child 1975, pp.245-246.
(21) Hodgson 1961, pp.720-721, figs.13-18; Kuwahara 1966, pp.235-236, figs.12f and 22a.
(22) Hodgson 1961, pp.723-724, figs.23-24; Kuwahara 1966, p.224, fig.19a; Allison & Child 1975, pp.263-264.
(23) Kuwahara 1960, p.22, fig.8; Kuwahara 1966, p.236.
(24) Hodgson 1961, pp.714-717, figs.1-5; Kuwahara 1966, pp.236-237, fig.11b; Allison & Child 1975, pp.262-263.
(25) Hodgson 1961, pp.717-718, figs.6-9; Kuwahara 1966, pp.223-224, fig.12b; Allison & Child 1975, pp.261-262, all as *M. hamata* Lindb., an illegitimate name according to Engel (1976).
(26) Hodgson 1961, pp.721-723, figs.19-22; Kuwahara 1966, pp.215-216, fig.16, as *Austrometzgeria saccata*.
(27) Hässel de Menendez 1961a, pp.268-270, figs.3-4; Allison & Child 1975, p.237.
(28) Bastow 1888, p.269, plate XXXI; Allison & Child 1975, pp.246-247.
(29) Hässel de Menendez 1961b, pp.255-259, figs.9-10; Campbell *et al.* 1975, pp.593-600, fig.2; Allison & Child 1975, pp.238-241, all as *S. hymenophyllum*.
(30) Schuster & Scott 1969, pp.233-238, figs.1-2, 4-7; Allison & Child 1975, pp.232-233.
(31) Schuster & Scott 1969, pp.248-250, figs.1-2, 4-5.
(32) Campbell 1959, pp.245-254, figs.1-33, as *Calobryum gibbsiae*; Schuster 1967, pp.21-28, figs.IX-X; Hässel de Menendez 1970, pp.235-238, fig.1.
(33) Bastow 1888, p.242, plate XVI; Hodgson 1958, pp.581-582, fig.7.
(34) Grolle 1962, pp.135-144, figs.1-4.
(35) Bastow 1888, p.243, plate XVII, as *L. drummondii*; Hodgson 1958, p.582; Allison & Child 1975, pp.191-192.
(36) Bastow 1888, p.241, plate XVI; Grolle 1963a, pp.391-394, fig.121.
(37) Bastow 1888, p.241, plate XVI; Hodgson 1958, pp.573-575, fig.2; Allison & Child 1975, pp.185-187.
(38) Bastow 1888, p.235, plate XII; Allison & Child 1975, pp.193-194.
(39) Bastow 1888, p.243, plate XVII; Engel 1968, pp.109-112, figs.326-464.
(40) Engel 1968, pp.106-108, figs.276-325.
(41) Hodgson 1949a, pp.29-30; Hatcher 1960, pp.602-604, figs.483-558. We are herein treating *Isotachis grandis* Carringt. & Pears. as a likely synonym.
(42) Grolle 1964a, pp.27-29, fig.4. Previously known only from the type in New Zealand.
(43) Schuster 1972, pp.190-193; Allison & Child 1975, pp.195-196.
(44) Schuster 1972, pp.190-212. Differs from *C. exiliflora* in that the cells are armed with spinous teeth; plants green, not becoming reddish. A thorough revision of this genus is needed.
(45) Hodgson & Allison 1962, pp.152-154, figs.35-39, as *Anoplostomum whiteleggei*; Schuster 1974, pp.172-174, fig.1.
(46) Schuster 1966a, pp.279-280.
(47) Grolle 1980b, pp.326-327; Grolle 1975a, pp.71-74, fig.1, as *H. filarium*.
(48) Carrington & Pearson 1888, pp.8-9, plate XLI, as *Cesia erosa*; Grolle 1966a, pp.231-234, fig.4.
(49) Carrington & Pearson 1888, pp.9-10, plate XLII, as *Jungermannia teres*; Grolle 1966a, pp.222-226, fig.2.

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

(50) Bastow 1888, pp.248-249, plate XXI, as *Sendtnera juniperina*. Similar to, but generally considered to be specifically distinct from *H. alpinus* (Steph.) Hodgs., illustrated in Allison & Child 1975, pp.37-38.
(51) Fulford & Hatcher 1961, pp.348-351; Allison & Child 1975, pp.38-40.
(52) Hattori 1979a, pp.328-329, fig.4.
(53) Hattori 1979a, pp.336-337, fig.10; also pp.340-342, fig.13, and pp.361-362, fig.27 as *F. forsythiana* and *F. wattsiana* respectively.
(54) Hattori 1979a, pp.347-349, fig.18; also Hattori 1979b, pp.132-134, fig.36 as *F. hampeana*.
(55) Hattori 1979b, p.139; also pp.131-132, fig.35, as *F. falsa*.
(56) Bastow 1888, pp.265-266, plates XXIX and XXXVI, as *Frullania diplota*; Hattori 1979a, pp.352-353, fig.21.
(57) *F. deplanata* Mitt. and *F. subdeplanata* Steph. are probably conspecific as both have flattened perianths lacking ventral keels; Hodgson 1949b, pp.380-381, figs.19-20 as *F. subdeplanata* and *F. deplanata*; Allison & Child 1975, pp.217-218, as *F. deplanata*.
(58) Allison & Child 1975, pp.93-94.
(59) Schuster 1966a, pp.280-281.
(60) Grolle 1971, pp.19-22, fig.4; Allison & Child 1975, pp.98-101.
(61) Allison & Child 1975, pp.94-95.
(62) Grolle 1971, pp.81-85, fig.22; Allison & Child 1975, pp.102-103.
(63) Grolle 1971, pp.55-59, fig.15; Allison & Child 1975, pp.101-102.
(64) Váňa 1975, pp.299-303, figs.17-19; Allison & Child 1975, pp.97-98.
(65) Váňa 1975, pp.303-306, figs.19-21; Possibly just an aquatic form of *Jungermannia inundata*.
(66) Schuster 1968, pp.484-485; Schuster & Engel 1975, p.469.
(67) Schuster 1963, p.245.
(68) Schuster 1963, p.245.
(69) Grolle 1975b, pp.75-79, fig.1; Allison & Child 1975, pp.228-229, both as *Diplasiolejeunea lyratifolia*.
(70) Grolle 1980a, pp.239-243, fig.2.
(71) Bastow 1888, pp.258-259, plate XXVII, as *Lejeunea gunniana*.
(72) Scott 1960, pp.152-154, figs.60-95.
(73) Grolle 1967, pp.20-24, figs.5-6; Allison & Child 1975, pp.54-55.
(74) Grolle 1967, pp.43-46, figs.13-14.
(75) Grolle 1967, pp.46-47, fig.13.
(76) Hodgson 1954, pp.21-22, fig.14.
(77) Hodgson 1954, pp.13-14, figs.2 and 7; Allison & Child 1975, pp.82-85. *B. involuta* (Mont.) Trev. is possibly another form of this highly variable species.
(78) Hodgson 1954, pp.10-11, fig.5.
(79) Herzog 1951, pp.488-491, figs.6-7, as *Lembidium isodictyon*; Grolle 1966b, p.229.
(80) Herzog 1951, pp.491-494, figs.8-9, as *Lembidium stereophyllum*; Grolle 1966b, pp.229-230.
(81) Hodgson 1956, p.615, as *Lepidozia hippuroides*; Carrington & Pearson 1888, pp.2-3, plate XXXVII, as *Lepidozia capillaris* var. *geniculata*; *Kurzia compacta* (Steph.) Grolle is treated herein as probably conspecific; cf. Hodgson 1956, p.616, fig.27, as *Lepidozia compacta*.
(82) Grolle 1963b, p.174; Grolle 1964b, p.80.
(83) Hodgson 1956, pp.594-596, fig.3; Allison & Child 1975, pp.64-65.
(84) Hodgson 1956, p.597, fig.5; Allison & Child 1975, p.66.
(85) Hodgson 1956, pp.601-602, fig.10; Allison & Child 1975, pp.71-72.
(86) Hodgson 1956, pp.593-594, fig.2; Allison & Child 1975, pp.63-64.
(87) Hodgson 1956, pp.605-606, fig.16, as *Lepidozia centipes*; Allison & Child 1975, pp.76-77.
(88) Hodgson 1956, pp.609-611, fig.20, as *Lepidozia gottscheana*; Allison & Child 1975, pp.77-78.

TABLE 3 (CONT.)

THE LIVERWORTS OF THE MT WELLINGTON RANGE

(89) Scott 1969, pp.165-168, figs.2-3; Allison & Child 1975, pp.90-91.
(90) Scott 1969, p.169, figs.1, 6-7; Allison & Child 1975, pp.90-91.
(91) Hodgson 1943, p.42, fig.12.
(92) Hodgson 1943, pp.36-37, fig.25; Allison & Child 1975, pp.144-145.
(93) Hodgson 1943, pp.41-42, fig.8; Allison & Child 1975, pp.146-149.
(94) Hodgson 1943, pp.45-46, fig.10.
(95) Hodgson 1943, pp.48-49, fig.13; Allison & Child 1975, pp.150-151.
(96) Rodway 1917, p.102.
(97) Bastow 1888, p.239, plates XV & XXXIX.
(98) Hodgson 1943, pp.47-48, fig.20; Allison & Child 1975, pp.147, 149-150.
(99) Bastow 1888, p.239, plate XIV; Hodgson 1943, pp.46-47, fig.14.
(100) Bastow 1888, p.233, plate XII, as *Jungermannia marginata*.
(101) Hodgson 1953, pp.338-339, fig.10, as *Lophocolea strongylophylla*.
(102) Engel 1979, pp.103-107, fig.7.
(103) Engel 1979, pp.98-103, fig.5.
(104) Schuster 1963, pp.269-270; Hodgson 1943, p.45, fig.7, as *Chiloscyphus laxus*.
(105) Bastow 1888, p.225, plate VI, as *Leioscyphus chiloscyphioides*. The relationship of this species to *Leptoscyphus expansus* (Lehm.) Grolle and *Leptoscyphus australis* (Hook.f. & Tayl.) Schust. needs study.
(106) Hodgson 1953, pp.354-355, fig.32; Allison & Child 1975, pp.140-141; see footnote 109.
(107) Rodway 1917, p.91.
(108) Hodgson 1953, pp.337-338, fig.11, as *L. notophylla*.
(109) Hodgson 1953, pp.350-351, fig.27; Allison & Child 1975, pp.136-137. Extraordinarily variable vegetatively; possibly *L. subporosa* Mitt., *L. decurrens* Herz., and even *L. bidentata* (L.) Dum., together with this, are all forms of a single species.
(110) Hodgson 1953, pp.343-344, fig.19; Allison & Child 1975, pp.132-133.
(111) Hodgson 1953, pp.342-343, fig.18; Allison & Child 1975, pp.131-132.
(112) Hodgson 1953, pp.334-335, fig.8, as *L. heterophylloides*; Allison & Child 1975, pp.130-131.
(113) Inoue & Schuster 1971, pp.173-180, figs.61-63.
(114) Inoue & Schuster 1971, pp.123-130, figs.44-45.
(115) Inoue & Schuster 1971, pp.180-187, figs.64-66.
(116) Inoue & Schuster 1971, pp.77-82, figs.26-27.
(117) Inoue & Schuster 1971, pp.110-115, figs.40-41.
(118) Inoue & Schuster 1971, pp.117-121, figs.42-43.
(119) Inoue 1980, pp.141-144, figs.1-10. This new species, described from a collection on Mt Wedge, is widespread on many Tasmanian mountains.
(120) Inoue & Schuster 1971, pp.203-213, figs.72-74.
(121) Inoue & Schuster 1971, pp.131-138, figs.46-48.
(122) Hodgson 1972, p.111; Hodgson 1967, fig.5; Schuster 1966b, pp.69-73, fig.1, the latter two as *I. murrayana*.
(123) Schuster 1966c, pp.351-355, figs.48-50.
(124) Castle 1967, pp.70-74, fig.34; Allison & Child 1975, pp.201-202.
(125) This is probably a group of species characterized by an inflated lobule and by cells that tend to be somewhat mamillose, including *R. compacta* Castle 1963, pp.43-45, fig.20, *R. tasmanica* Steph. (Castle 1963, pp.36-38, fig.17), *R. tabularis* Steph. (Castle 1963, pp.38-41, fig.18), *R. aneurysmalis* (Hook.f. & Tayl.) Gott. (Castle 1963, pp.28-30, fig.12) and *R. wattsiana* Steph. (Castle 1963, pp.45-47, fig.21).
(126) Allison & Child 1975, pp.104-105.
(127) Hodgson 1941, p.188, fig.31; Schuster 1971, fig.8; Allison & Child 1975, pp.116, 121-122.
(128) Hodgson 1941, pp.184-185, figs.10-11.
(129) Schuster 1968, pp.445-447, plate 50, figs.8-11; Ratkowsky 1980a, pp.79-80.
(130) Schuster 1968, pp.447-449, plate 50, figs.1-7; Ratkowsky 1980a, p.80.

Amongst the liverworts, several new Tasmanian records have been found in the survey area. Perhaps the most remarkable is *Neesioscyphus phoenicorhizus*, a very distinctive plant, of which we have material from at least six locations in the survey area. The species was previously known only from the type collection near Arthurs Pass in New Zealand (Grolle 1964a), and as all other known species of this genus grow in tropical localities, the taxonomic affinities of this species have not been established with certainty. *Chaetophyllopsis whiteleggei*, *Haplomitrium gibbsiae* and *Hygrolembidium australe* are also new to Tasmania, these records having been obtained in this survey. In addition, two other species, also obtained in this survey but not listed in table 3, were identified tentatively by Dr. R. Grolle (pers.comm.) as belonging to the genera *Cephalozia* (Dum.) Dum. and *Paracromastigum* Fulf. & J. Tayl. respectively. These could, upon further study and subsequent specific identification, also prove to be new Tasmanian records.

TABLE 4

NUMBER OF SPECIES IN EACH VEGETATION ZONE

	Zone							
	1	2	3a	3b	4	5	6	7
Mosses	43	62	62	78	108	61	102	82
Liverworts	34	70	63	50	69	25	67	29
Total bryophyte count	77	132	125	128	177	86	169	111

Table 4 lists the number of species in each vegetation zone, obtained by counting the entries in the columns of table 2 and table 3. Mosses have their maximum occurrence in the zones of middle and lower elevation, the greatest numbers being in Zones 4, 6, 7 and 3b. Liverworts occur most frequently in Zone 2, followed by Zones 4, 6 and 3a, with comparatively low numbers in the low elevation dry sclerophyll environments of Zone 7. Ogden and Powell (1979), from a study of woody plants at Mt Field National Park, Tasmania, concluded that species richness increases with altitude to reach a maximum in the subalpine zone. This conclusion does not hold for Mt Wellington, as a tally of woody species from the survey by Ratkowsky and Ratkowsky (1976) shows that the greatest abundance occurs in Zone 4 and Zone 7, the numbers declining distinctly in the higher elevation zones. The numbers in table 4 enable one to examine the effect of elevation on bryophyte richness. The greatest moss richness is seen to occur in the middle and lower zones, whereas liverworts are spread out over a wide range of altitudes, although they are relatively scarce in Zones 5 and 7.

One may examine the question further by grouping closely related zones and counting the number of species that occur exclusively in one zone group. The basis for grouping the zones was taken from Ratkowsky and Ratkowsky (1977), where several methods of hierarchical cluster analysis were used. It was found that Zones 3b, 4 and 6 clustered to form a gully/wet sclerophyll forest group; Zones 1, 2 and 3 formed a high elevation group of treeless or woodland habitats; Zone 7 formed a dry sclerophyll forest group of its own; and Zone 5 had no close neighbour and could not be grouped with other zones. Table 5 lists the number of species restricted to one of the following three zone groups, with Zone 5 omitted: any or all of Zones 1, 2 and 3a; any or all of Zones 3b, 4 and 6; exclusive to Zone 7.

The results in table 5 show that the mosses occur predominantly in the gully/wet sclerophyll forest group, with much smaller numbers of species occurring either in the high elevation group or dry sclerophyll. The liverworts, however, exhibit a different pattern, with half the species in table 5 occurring in the high elevation zone group. An almost equally large number of liverwort species occurs in the gully/wet sclerophyll zone group, with only three species being exclusive to dry sclerophyll forest. The

TABLE 5

NUMBER OF SPECIES RESTRICTED TO CERTAIN ZONE GROUPINGS
(omitting Zone 5 from consideration)

	Species occurring only in Zones 1, 2 and/or 3a	Species occurring only in Zones 3b, 4 and/or 6	Species occurring only in Zone 7
Mosses	16	42	13
Liverworts	35	32	3

results in table 4 and table 5 indicate that mosses predominate in the middle zones (gullies and wet sclerophyll communities) but are also relatively abundant in the lower elevations (dry sclerophyll), whereas liverworts are abundant both at middle and higher elevations but are relatively infrequent in the dry sclerophyll forests.

Only a few species previously known to have occurred on Mt Wellington, from citations in Rodway (1913-14, 17) or from specimens preserved in the Tasmanian Herbarium, have not been found in the present survey. The largest and most striking of these is *Neckera pennata* Hedw., a pendent species previously known from a few east-facing gullies. The current absence of this species from Mt Wellington may be traced to alienation of environment as a result of land clearance and house building, or may be due to the devastating bushfire of 7 February 1967. Although there has clearly been a strong recovery of the bryophyte flora since the fire, as evidenced by the large number of species found in this survey, epiphytic species are slow to recover, and it may be expected that, barring further fires, various epiphytic moss and liverwort species presently missing may be found on Mt Wellington in the future.

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THE VEGETATION OF SCHOUTEN ISLAND, TASMANIA

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(with three tables, seven text-figures and ten plates)

ABSTRACT

HARRIS, S. and KIRKPATRICK, J.B., 1982 (31 viii): The vegetation of Schouten Island, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 117-141. ISSN 0080-4703. National Parks and Wildlife Service, and University of Tasmania, Hobart, Tasmania.

Thirty-seven communities defined by structure and dominance are mapped for Schouten Island which lies within the Freycinet National Park on the east coast of Tasmania. The communities dominated by herbs are mainly coastal in occurrence, those dominated by shrubs are mostly confined to the granitic east of the island, and those dominated by trees are most widespread on the dolerite and sandstone of the west. Thirteen floristic communities are recognized as a result of a monothetic divisive classification of species lists from 160 quadrats. The distribution of these communities, like that of the structure-dominance communities, is most closely related to surface geology and exposure to salt-laden winds. However, their structural expression, and to some extent their distribution, is moulded by other influences such as fire incidence and intensity, topography, and disturbances by man and other animals. Over 450 native higher plant species are recorded for the Freycinet National Park.

INTRODUCTION

Schouten Island is situated immediately south of Freycinet Peninsula on Tasmania's eastern coast. It covers an area of 3 439 hectares, and is mountainous and rugged with a predominantly cliffed coastline. The highest peak, Mt Storey, is 400 m high. The island is similar in topography and lithology to Freycinet Peninsula, from which it is separated by a narrow passage about one km in width. Its vegetation contains elements of the dolerite-dominated landscape to the south and the granite-dominated landscape to the north. Schouten Island is part of the Freycinet National Park which with Mt William National Park, Maria Island National Park and Strzelecki National Park contains almost all the reserved natural vegetation in the drier part of the State. Thus, the description of the vegetation of the island given in this paper serves both to make more accurate our knowledge of the plant community composition of the Tasmanian State Reserve system (Specht *et al.* 1974) and to enlarge the published descriptions of the vegetation of "dry" Tasmania (Stephens and Cane 1939; Hogg and Kirkpatrick 1974; Bowden and Kirkpatrick 1974; Kirkpatrick 1973, 1975, 1977, 1981,; Kirkpatrick *et al.* 1980; Brown and Bayly-Stark 1979; Harris and Brown 1980; Wells *et al.* 1977).

There are no climatic data available for Schouten Island but precipitation and temperature conditions are probably approximated by data from the nearest station at Swansea (table 1).

The most striking feature of the geology of the island is the north-south trending fault through the centre of the island. The fault divides the upthrown granite in the east from the downthrown dolerite-capped sedimentary rocks in the west. Sandstone outcrops beneath the dolerite along parts of the western coast. The sandstone beds contain coal measures and form extensive cliffs (plate 1). The sandstone is also exposed in two of the deeper western gullies. Mudstone occurs in a small area next to the granite margin behind Sarah Ann Bay. A sheet of leached sand, probably of aeolian origin, and of variable

Vegetation of Schouten Island, Tasmania

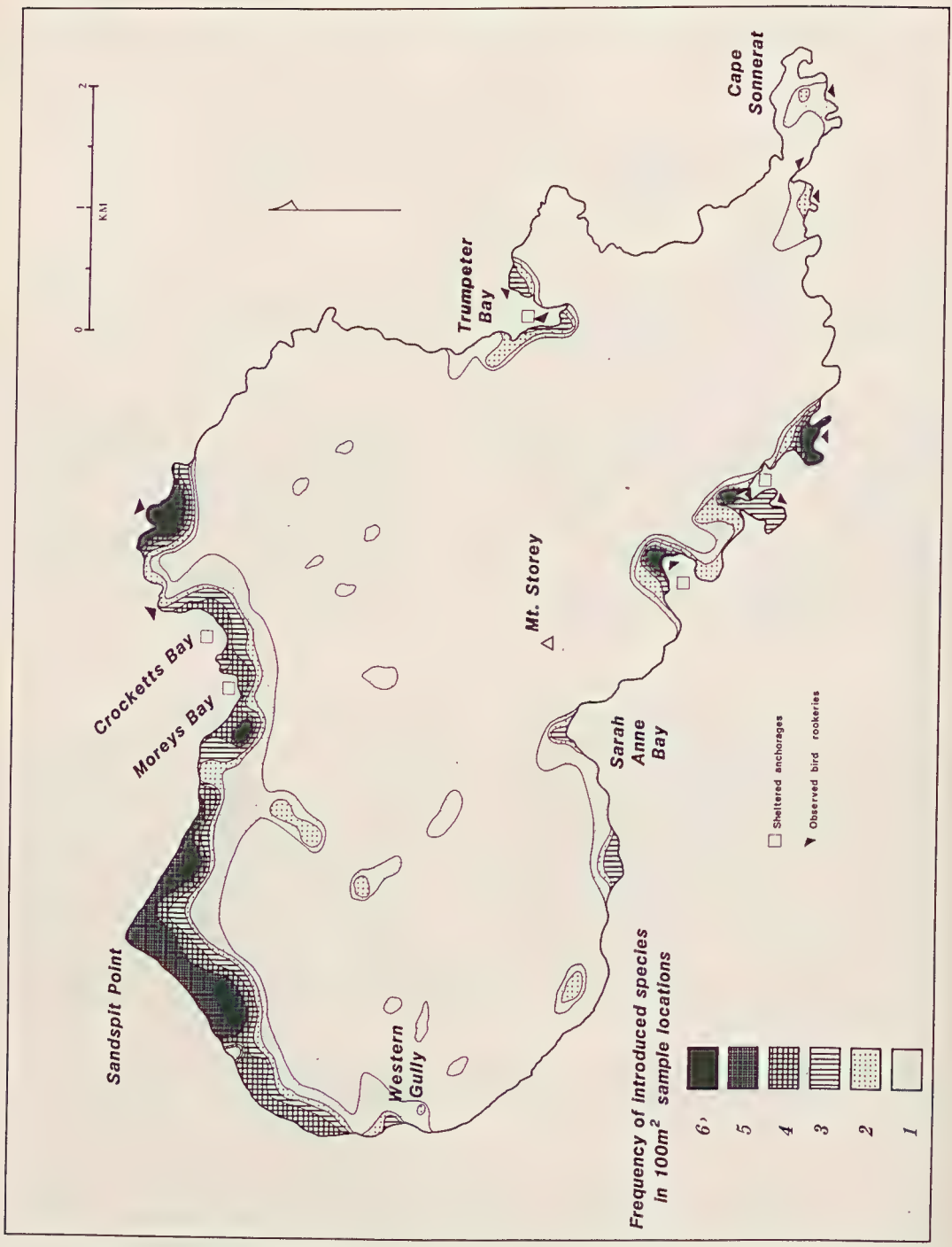

FIG. 1 - The distribution and density of exotic plant species on Schouten Island based on data from 140 quadrats.

TABLE 1

CLIMATIC DATA FOR SWANSEA

A = precipitation (mm); B = no. of raindays (prec. > 2.5 mm);
C = mean daily maximum temperature (°C); D = mean daily minimum temperature (°C).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
A	41	48	63	58	42	64	50	35	38	55	47	62	604
B	9	8	10	11	12	12	12	12	12	13	11	11	131
C	21.6	21.9	20.4	17.7	15.2	12.9	12.6	13.6	15.5	17.4	19.3	20.7	
D	11.2	11.7	10.2	8.1	5.8	4.4	3.8	4.2	5.7	7.2	8.8	10.3	

depth covers part of the dolerite in the west and is probably of Last Glacial Age. Calcareous marine sand is being deposited on Sandspit Pt.

The soils of the island vary from the highly acid (pH = 4.5) podzols on aeolian sand and peats on granite colluvium, to the near neutral and relatively fertile soils formed *in situ* on dolerite and sandstone (fig. 3). Young soils include those formed on alluvium in a few valleys where they often exceed 0.5 m in depth, calcareous undifferentiated coastal sands and lithosols on both granite and dolerite. On the eastern part of the island these lithosols form the extreme of a catena of increasing depth of the coarse weathering products of granite which terminates in the acid peats of the ill-drained slope-base flats. On the western half of the island the lithosols are actually the finer material held between and beneath the dolerite talus of south-east facing slopes (plate 2).

METHODS

Photocommunities were mapped from 1:40 000 black and white aerial photographs. These photocommunities were defined primarily by structural characteristics (Specht 1970) and secondarily by phototexture and tone.

The fieldwork commenced in early January 1977 and continued until the beginning of March 1977 and then proceeded intermittently in June and August 1977. Plant collections were made during these periods and in December 1981. Voucher specimens are held in the Geography Department, University of Tasmania and the Tasmanian Herbarium.

One hundred and sixty square 100 m^2 quadrats were located using the "subjective without preconceived bias" approach (Mueller-Dombois and Ellenberg 1974). Sample sites were selected to include as wide a range of physiognomically different vegetation as possible. Within each quadrat the following data were recorded: a list of all species present, pH of the A_1 soil horizon (measured with a C.S.I.R.O. field testing kit), the structure of the vegetation, whether the vegetation in the quadrat was exposed to salt spray, the extent of drainage or waterlogging of the soil (qualitatively described), the surface geology, aspect and signs of human influence and firing.

General information on current human influence was gained from conversations with local people including Mr R. Maxfield, a local fisherman. Information of European activities on the island, dating from the 1820's, was gleaned from files in the Archives Office of Tasmania.

The monothetic, divisive computer programme, DIVINF, was used to classify the quadrats. The Chi-squared statistic was used to gain an indication of the strengths of the relationships between the environmental variables and the 101 most frequent plant species and between every possible pair of these species.

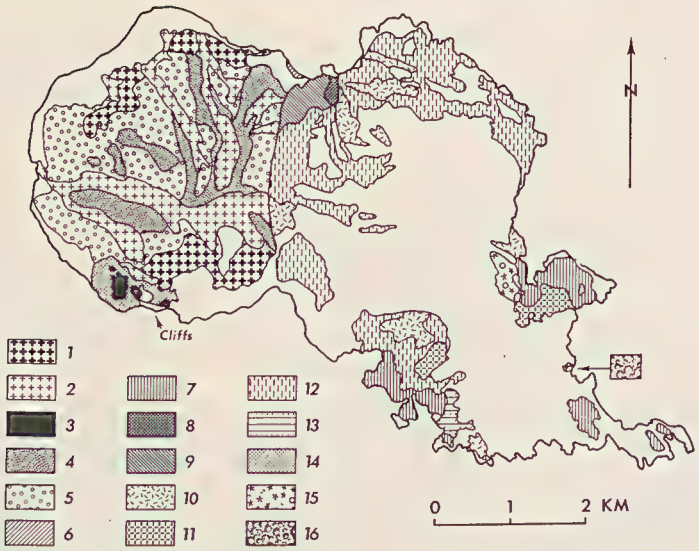

FIG. 2 - Distributions of plant communities dominated by trees. 1 - *Eucalyptus globulus* tall open-forest; 2 - *E. globulus* open-forest; 3 - *Bedfordia salicina-Notelaea ligustrina* low closed-forest; 4 - *E. amygdalina-E. pulchella* open-forest; 5 - *E. amygdalina-E. viminalis* open-forest; 6 - *Casuarina stricta* low open-forest; 7 - *C. stricta* low closed-forest; 8 - *E. amygdalina-C. littoralis* low open-woodland; 9 - *E. amygdalina-C. littoralis-B. marginata* low open-forest; 10 - *E. tenuiramis-E. obliqua-E. ovata* open-forest; 11 - *E. tenuiramis-E. amygdalina* open-forest; 12 - *E. tenuiramis-Callitris rhomboidea* low open-forest; 13 - *Casuarina stricta* low woodland; 14 - *C. stricta* low open-woodland; 15 - *E. amygdalina* low open-woodland; 16 - *E. amygdalina-Callitris rhomboidea* low closed-forest.

RESULTS

The Human Influence

Charcoal is common in aboriginal middens in the north, west and south of the island indicating a long history of firing of the island by aboriginals gaining access by canoe from the Freycinet Peninsula (an early painting shows such access). With the replacement of aboriginal activities by those of Europeans from about 1810, fire frequency was at least maintained, if not increased. Fires were mainly associated with grazing and mining.

As well as firing, Europeans cleared some land and caused exotic species to be introduced. These effects on the vegetation began quietly enough with whalers putting to shore while sheltering from storms. In the 1820's a small whaling station was constructed at Crocketts Bay.

Pasturing of sheep began in the northwestern corner of the island in the early 1840's and continued sporadically until the 1920's. From this time sheep were run more or less continuously until April 1978. Milligan (1848, p.2) mentioned "that from 200 to 300 sheep have at one time run and improved in condition upon the island". The maximum number of sheep on the island was probably 650, in 1960 and 1961, when they occupied part of a lease covering the whole island.

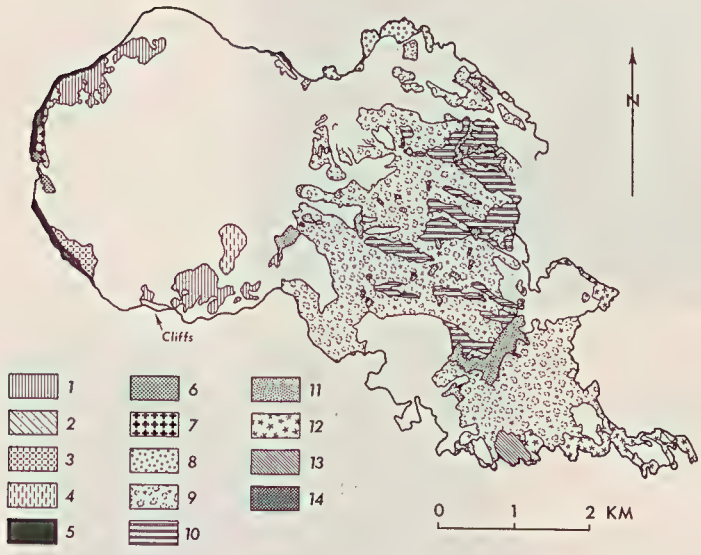

FIG. 3 - Distributions of plant communities dominated by shrubs, ferns and sedges. 1 - *Pteridium esculentum-Lomandra longifolia* closed fernland; 2 - *Ulex europaeus* closed-heath; 3 - *Helichrysum costatifructum-Gahnia radula* open-heath; 4 - *Acacia verticillata-A. melanoxylon-Olearia viscosa-Bursaria spinosa* closed-scrub; 5 - *Alyxia buxifolia-Calocephalus brownii* low open-shrubland; 6 - *Lomandra longifolia-Gahnia radula* closed-sedgeland; 7 - *Casuarina stricta-Banksia marginata* open-heath; 8 - *Acacia mucronata-Eucalyptus amygdalina* closed-scrub; 9 - *E. amygdalina-Banksia marginata-Leptospermum* tall open-shrubland; 10 - *Leptospermum* spp.-*Hakea* spp.-*E. amygdalina* open-scrub; 11 - closed-heath and closed tussock sedgeland; 12 - *Alyxia buxifolia-Helichrysum reticulatum* low open-shrubland; 13 - *Goodenia ovata* closed-heath; 14 - *Bedfordia salicina-Notelaea ligustrina* closed-scrub.

Pasture species as well as weeds were introduced with sheep. Some of these exotic species have become well established on the island. *Ulex europaeus* was certainly introduced with sheep as it is a common "vegetable fault" in wool (Hyde-Wyatt and Morris 1975). It has invaded parts of the eucalypt open-forest on the dolerite, aided by the sheep, which previously ran freely on the western portion of the island.

Coal mining probably began in the 1840's. A jetty was constructed at Crocketts Bay and a railway line built along the coast connected the jetty with the mine near Sandspit Point. Some very high concentrations of exotic species occur along this route (fig. 1). Trees were undoubtedly felled for construction purposes, and accidental and deliberate fires probably occurred. Coal mining was a short-lived industry. In the 1880's a few Chinese worked alluvial tin sluices on the upper reaches of the creek named after them, but this also was a short-lived activity. Repeated, brief attempts at mining occurred from time to time until about 1925.

Figure 1 gives an indication of introduced species concentrations but the pattern does not faithfully reflect areas of human disturbance as bird rookeries determine the location of exotic species infestations over much of the island.

The highest counts of exotic species were in areas disturbed by man or his domestic animals. For example, fourteen exotic species were recorded for quadrat 20 on the closed-

PLATE 1

Sandstone cliffs on the west coast of the island. *Stipa stipoides* dominates a narrow zone near the coast. *Casuarina stricta* is mostly dominant elsewhere. A small group of *Callitris rhomboidea* trees is visible at the base of the cliff in the right foreground.

PLATE 2

Bedfordia salicina-Notelaea ligustrina low closed-forest among dolerite talus.

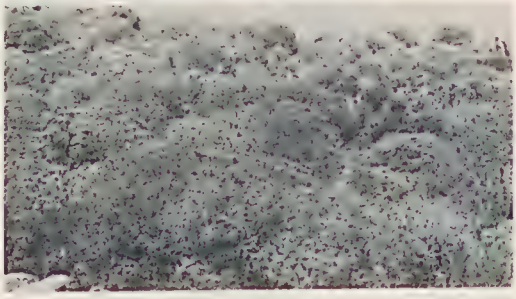

PLATE 3

The granitic eastern part of the island looking towards Cape Sonnerat. *Casuarina stricta* forms a low closed-forest in the left middleground.

PLATE 4

Eucalyptus amygdalina-E. pulchella open-forest with the grassy understorey typical of much of the drier slopes on dolerite.

grassland, and five species were recorded for quadrat 1, also on closed-grassland. The heavily burned and grazed areas had large numbers of exotics. Such areas on the coast at Sarah Ann Bay had fewer, perhaps because of the distance from the node of animal and plant introduction, considered to be in the Moreys Bay area.

Many bays and inlets, some of which are convenient for boat anchorages, also have high weed concentrations. A small amount of exotic species introduction may have been accomplished by landing parties from fishing and pleasure craft. In such cases plants might become established from seeds that were lodged in boots or clothing. Exotic species are also concentrated on the phosphorus-enriched bird rookeries (fig. 1). At least 44 exotic plant species are found on the island.

Despite the many changes wrought accidentally and deliberately by European man the vegetation of the island looks basically the same today as when described by Milligan (1848, p.8):

> "The remaining third of the surface of the Island consists of greenstone eminences; lofty and barren enough for the most part, but still more undulating and rounded in their outline, and more prolific of vegetation and timber trees, than the granite section, which, except in deep ravines, and around the base of the hills, supports, only, and at long intervals, a scanty show of scrubby and stunted plants.
>
> On the more gentle slopes of the greenstone hills, and their varied undulations, there is besides a forest of gum trees, many stately specimens of Oyster Bay pine with a good deal of grass and other herbage fit for sheep and cattle."

Floristics

The species list (Appendix) includes almost 500 taxa of which 450 species are native to the Freycinet National Park. Of the native species 104 have been recorded from Schouten but not the Freycinet Peninsula and 111 have been recorded for the Freycinet Peninsula but not from Schouten Island. Thus 235 native species are held in common, Freycinet being richer in nanophanerophytes and orchids than Schouten and Schouten being richer in grasses and forbs than Freycinet. Endemism is relatively low with 32 of the 450 native species being Tasmanian endemics, 20 being found on the Freycinet Peninsula and 23 on Schouten Island. The slightly higher proportion of Tasmanian endemic species on Schouten Island may be accounted for by the large area of dolerite on Schouten (Kirkpatrick 1981).

Of the 436 native species recorded from Maria Island to the south (Brown and Bayly-Stark 1979) 287 are also recorded for the Freycinet National Park. The distinct granitic environment of most of the Freycinet Park may partially account for the differences between the two adjacent parks. Some of the species found on the granite of the Freycinet National Park have highly disjunct distributions, with a marked gap between the peninsula and either the Furneaux Group or the mainland (e.g. *Thryptomene micrantha*, *Pseudanthus ovalifolius*, *Gahnia microstachya*).

Structure and Dominance Patterns

(a) Communities dominated by trees

To the west of the fault line forests cover most of the land, whereas forests cover less than 40% of the granite and granitic colluvium (fig. 2, plate 3). The dominant species are mostly eucalypts, although *Casuarina* spp., *Callitris rhomboidea*, *Bedfordia salicina* and *Notelaea ligustrina* also dominate some areas (fig. 2, plates 1, 2 and 3).

Eucalyptus globulus tall open-forest and open-forest is restricted to south-facing slopes, deep gullies and limited areas of relatively deep soils on gentle slopes, all on dolerite, in the western half of the island. The understorey consists largely of open-grassland. However, the potential understorey in the mesic environment occupied by this

community is probably closed-scrub dominated by a mixture of broad-leaved and sclerophyllous tall shrubs, a type which is most common on the island in the tall open-forest.

E. amygdalina and/or *E. pulchella* and their intermediates dominate open-forest on ridges and steep north-facing slopes on dolerite. The understorey consists of a low open cover of grasses, herbs and chamaephytes (plate 4). Where sands cover the dolerite and on the podzolic soils formed on sandstone *E. amygdalina* is generally codominant with *E. viminalis*, except in flat ill-drained areas where *E. ovata* dominates and on the driest slopes where *E. viminalis* is absent. The understorey is dominated by *Pteridium esculentum* and *Lepidosperma* spp. where fire has been recent and by sclerophyllous shrubs where five or more years have elapsed since the last fire (plate 5).

E. amygdalina is codominant with *Casuarina littoralis* in deep sands over granite in the northern part of the island where they form a low open-forest to low open-woodland with a closed-heath understorey under the eucalypt and virtually no plant cover under the *Casuarina*. In the eastern part of the island tree-form *E. amygdalina* is most widely associated with *E. tenuiramis* and *Callitris rhomboidea* in open-forest and low open-forest in well-drained slopes and gullies (plate 6). The open-forest consists largely of *E. tenuiramis*, especially in the north, *E. amygdalina* and *E. obliqua* being codominants on the southern slopes of Mt Daedalus. The understorey is an open to closed-scrub dominated by a mixture of broad-leaved and sclerophyllous shrubs, among which *Callitris rhomboidea* can be prominent. The low open-forest tends to occur in areas where granite boulders occupy much of the ground, the remaining ground cover being open-heath. The sparse understorey and the protection of the boulders are probably responsible for the survival of the fire-sensitive *Callitris rhomboidea* as a codominant in much of the area of this community. *C. rhomboidea* and *E. amygdalina* codominate a low closed-forest in another fire-protected situation below the eastern cliffs of the island. Communities dominated by trees of *Casuarina stricta* occur close to the coast in three structural forms (fig. 2). *C. stricta* is a highly drought-resistant species (Ashton *et al.* 1975), is highly resistant to the effects of salt spray deposition and characteristically has an extremely sparse herb layer underneath its canopy. The sparse understorey gives some fire protection to dense stands of the species, which is readily killed by fire although recovering well from seed held in serotinous cones, root sprouts and occasionally basal shoots. The *Casuarina stricta* low open-woodland in the eastern part of the island is interspersed by *Poa poiformis* tussock grassland and the *C. stricta* low-woodland in the western half of the island is interspersed by fernland or open-heath dominated mostly by coastal species. The understorey of the low closed-forest is bare except for a thick mat of cladodes and infrequent herbs.

Small areas of low closed-forest dominated by *Bedfordia salicina* and *Notelaea ligustrina* occur in the midst of dolerite talus slope deposits in the southwestern sector of the island (plates 2 and 7). There is a sparse covering of ferns, grasses and small shrubs in the interstices between the boulders and on fallen logs. The community is extremely well-protected from fire, being surrounded by unvegetated talus, and having a completely closed-canopy consisting of non-inflammable species.

(b) Communities dominated by shrubs and sedges (fig. 3)

Scrub, heath and sedgeland communities dominate most of the eastern half of the island. Closed tussock-sedgeland and/or closed-heath dominated by *Gymnoschoenus sphaerocephalus* and/or myrtaceous shrub species have formed peat soils over deep granitic colluvium wherever drainage is impeded or slow, the sedgeland community occupying the areas of worst drainage. The surrounding granite topography presents an enormous variety of well-drained microhabitats. Those with the highest moisture status support the forests and woodlands described previously. These grade into open-scrub dominated by *E. amygdalina*, *Hakea* spp. and *Leptospermum* spp. with an extremely dense and tangled understorey, often dominated by *Gleichenia dicarpa*, in valleys and near the bases of south-facing slopes. This community grades into a tall open-shrubland to open-heath as soils become shallower and insolation more intense. *E. amygdalina*, *Banksia marginata* and *Leptospermum* spp. dominate much of this mapping unit. However, *Calytrix tetragona* dominates some of the more exposed and dry situations where soil is still present, *Crassula sieberana*, a succulent herb, occupies shallow, insolated cracks in the granite and lichens dominate the bare rock.

PLATE 5
Eucalyptus amygdalina dominant on a leached sand sheet with an understorey in which *Banksia marginata* and *Gahnia radula* are prominent.

PLATE 6
Eucalyptus tenuiramis-Eucalyptus amygdalina open-forest with a grove of *Callitris rhomboidea*.

PLATE 7
The interior of the *Bedfordia salicina-Notelaea ligustrina* low closed-forest.

PLATE 8
Acacia mucronata closed-scrub at Crocketts Bay.

Vegetation of Schouten Island, Tasmania

The only non-coastal area dominated by shrubs in the western half of the island is surrounded by *E. globulus* tall open-forest. This closed-scrub dominated by *Acacia melanoxylon* and *Bursaria spinosa* shows evidence of being in the recent past a forest community. Large eucalypt logs are found within its area.

The vegetation of the sandstone cliffs in the western half of the island is a low open-shrubland dominated by *Alyxia buxifolia* and *Calocephalus brownii* whereas on many of the granite cliffs the codominant of *A. buxifolia* is *Helichrysum reticulatum*. On the cliff tops to the rear of the *A. buxifolia-C. brownii* low open-shrubland the combination of salt spray deposition and firing has created two communities; an open-heath dominated by *Casuarina stricta* and *Banksia marginata* in the north and an open-heath dominated by *Helichrysum costatifructum* and *Gahnia radula* in the south in which *C. stricta* and

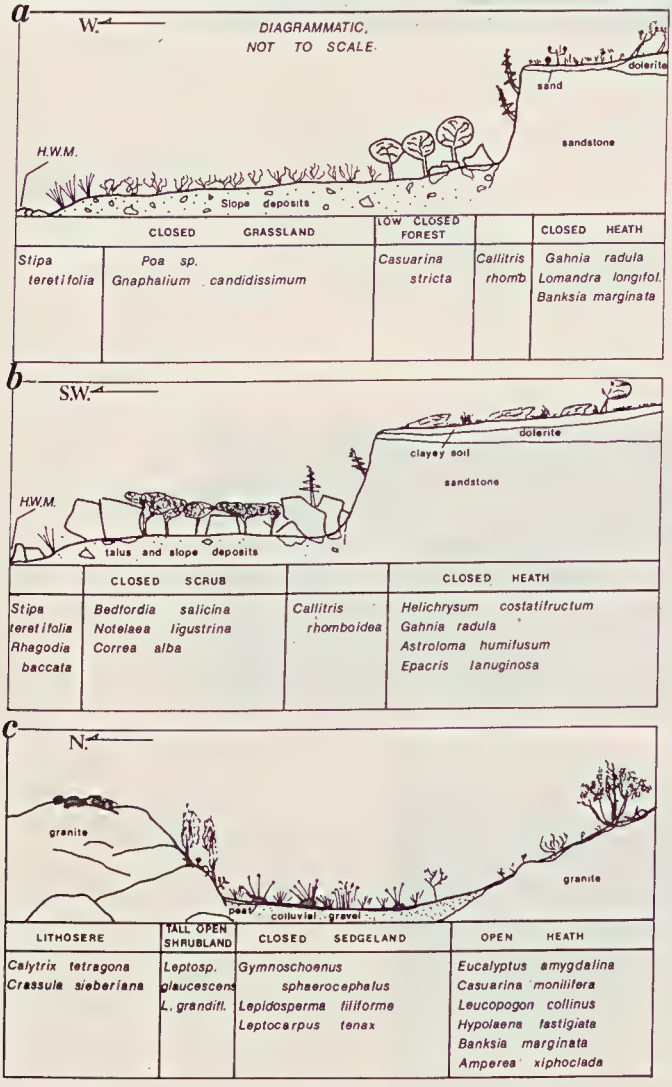

FIG. 4 - Schematic profiles of the coastal and granite vegetation. Note that *Stipa teretifolia* should read *Stipa stipoides*.

B. marginata are present (fig. 4). *Bedfordia salicina* forms a closed-scrub in talus at the base of the same cliffs (fig. 4). On some coastal granite slopes in the southern part of the island firing has probably reduced scrub vegetation to a closed-heath dominated by heavily salt-pruned *Goodenia ovata*. The major coastal community dominated by shrubs in the sheltered north of the island is closed-scrub dominated by *Acacia mucronata* (plate 8). The only mappable community dominated by an exotic is also found in the northern part of the island in the cleared area on dolerite at Moreys Bay where *Ulex europaeus* formed a closed-heath to closed-scrub before control operations in late 1981.

(c) Communities dominated by grasses and herbs (fig. 5)

Communities dominated by grasses or herbs are most widespread in the western part of the island and are mostly near-coastal and/or associated with human disturbance. The most extensive herbaceous communities are *Lomandra longifolia* open tussock-herbland and *Pteridium esculentum-Lomandra longifolia* closed-fernland (plate 9). Both these communities are located in the most intensely disturbed sections of the island where grazing, clearing and frequent firing have destroyed former forest communities which are now reinvading, and both communities have exotic species prominent in the lower strata. The small areas of *Poa poiformis* closed-tussock grassland and *L. longifolia* closed tussock-herbland at the mouth of Western Gully may also owe their origin to a combination of grazing and fire disturbance, and the area of *Themeda australis* closed-tussock grassland in the far northwestern sector of the island has probably resulted from clearing. However, a small near-coastal area of the same community in the southeastern part of the island is probably natural in origin.

Spinifex hirsutus open-grassland is confined to the northwestern sandspit where it is a colonizing community. The herbaceous communities of rocky coasts are only of mappable extent in the highly exposed southeastern part of the island. This mapping unit includes several zones, the distribution of which seems strongly related to exposure to saltspray. The zone closest to the sea is dominated by succulents, most notably *Disphyma australe* and *Carpobrotus rossii*. The latter species, as on the granite Bass Strait Islands where exactly the same zonation is apparent (Kirkpatrick *et al.* 1974), tends to occur to the landward of *D. australe*. *Stipa stipoides* tussock-grassland forms the next most landward zone with *Poa poiformis* tussock-grassland further inland.

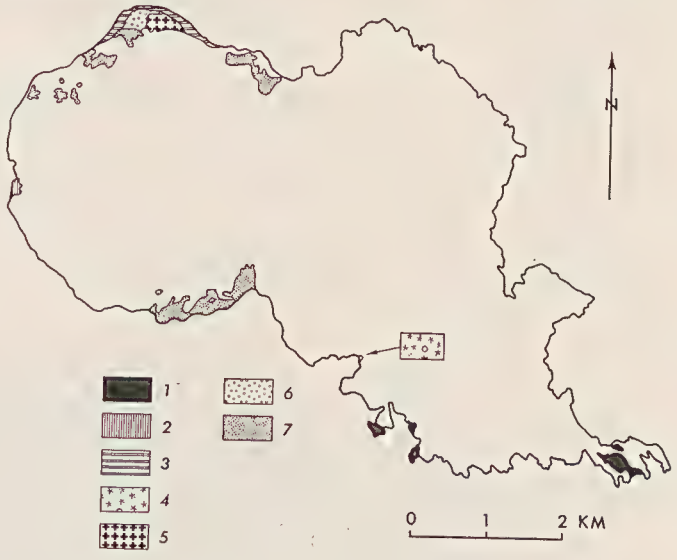

FIG. 5 - Distributions of the communities dominated by grasses and herbs. 1 - *Stipa stipoides* tussock grassland; 2 - *Poa-Danthonia* closed-grassland; 3 - *Cakile* ephemeral herbland; 4 - *Themeda australis* closed-grassland; 5 - *Poa-Themeda-Pteridium-Lomandra* grassland; 6 - *Ammophila arenaria-Spinifex hirsutus-Festuca littoralis* open grassland; 7 - *Lomandra longifolia* open herbland.

TABLE 2

PERCENTAGE FREQUENCY OF SPECIES BY DIVINF GROUPS.

Species	Group 4 n=8	Group 24 n=6	Group 25 n=12	Group 17 n=17	Group 16 n=10	Group 22 n=7	Group 23 n=13	Group 10 n=14	Group 8 n=18	Group 18 n=13	Group 19 n=18	Group 20 n=6	Group 21 n=18
Gymnoschoenus sphaerocephalus	100	-	-	-	-	-	-	-	-	-	-	-	-
Sprengelia incarnata	88	100	-	12	-	-	-	-	-	-	-	-	-
Selaginella uliginosa	63	17	-	-	-	-	-	-	-	8	-	-	6
Drosera pygmaea	50	50	-	-	-	-	-	7	-	-	11	-	-
Xyris spp.	50	-	8	-	-	-	-	-	-	-	-	-	-
Gleichenia spp.	75	-	17	-	-	-	-	-	-	8	-	-	-
Hakea teretifolia	75	100	100	-	-	-	-	-	-	-	11	-	-
Lepidosperma filiforme	88	100	50	18	10	-	-	-	-	-	-	-	-
Leptospermum scoparium	88	50	8	24	-	-	-	14	-	8	22	-	-
Leptocarpus tenax	75	83	8	12	-	29	-	-	-	-	-	-	-
Melaleuca squamea	50	17	8	6	-	-	-	-	-	-	6	-	-
Cassytha glabella	50	83	42	24	-	14	-	14	-	-	6	-	-
Bauera rubioides	75	83	25	24	10	-	-	-	-	-	6	-	-
Calorophus elongatus	88	17	33	6	-	-	-	-	-	-	6	-	-
Caustis pentandra	-	67	25	12	-	-	-	-	-	-	-	-	-
Gompholobium heugelii	-	50	33	35	-	-	-	-	-	-	-	-	-
Pseudanthus ovalifolius	-	50	42	12	-	-	-	-	-	-	6	-	-
Schoenus tenuissimus	-	50	33	12	-	-	-	-	-	-	-	-	-
Patersonia fragilis	-	50	-	-	-	-	-	-	-	-	-	-	-
Dillwynnia glaberrima	13	33	58	29	-	-	-	-	-	-	6	-	-
Leptospermum glaucescens	-	33	42	18	-	-	-	-	6	-	11	-	-
Tetratheca pilosa	25	17	58	12	-	14	-	7	-	-	-	-	-
Leucopogon collinus	13	100	75	53	10	14	-	21	-	-	6	-	-
Acacia genistifolia	13	67	100	53	30	14	-	14	-	-	11	0	6
Gonocarpus humilis	13	17	67	76	40	29	54	29	-	-	22	-	33
Lindsaya linearis	38	83	17	12	-	14	8	7	-	-	11	-	22
Acacia myrtifolia	38	100	58	71	40	14	23	7	-	-	6	-	-
Amperea xiphoclada	-	67	83	65	30	14	15	-	-	-	6	-	6
Spyridium vexilliferum	-	17	17	6	10	43	8	29	-	-	-	-	6
Xanthosia pilosa	13	33	92	53	10	14	8	-	-	-	-	-	-
Xanthosia tridentata	-	50	58	53	20	14	-	-	-	-	-	-	-
Epacris impressa	-	100	100	100	100	-	-	100	-	-	-	-	-
Eucalyptus amygdalina	13	67	67	53	50	100	100	64	-	-	-	-	-
Hibbertia riparia	13	67	83	59	60	100	-	43	-	-	6	17	-

TABLE 2 (cont.)

Species	Group 4 n=8	Group 24 n=6	Group 25 n=12	Group 17 n=17	Group 16 n=10	Group 22 n=7	Group 23 n=13	Group 10 n=14	Group 8 n=18	Group 18 n=13	Group 19 n=18	Group 20 n=6	Group 21 n=18
Gonocarpus tetragynus	13	-	17	18	40	71	8	43	11	-	6	50	11
Correa reflexa	25	-	8	6	20	43	15	7	-	-	11	-	6
Banksia marginata	50	83	92	82	50	57	54	50	6	-	28	17	6
Stylidium graminifolium	25	100	83	71	70	14	8	36	6	31	22	-	11
Lepidosperma concavum	-	67	92	88	60	43	31	50	6	8	22	-	6
Dampiera stricta	-	33	8	24	10	-	-	7	11	54	17	17	6
Calytrix tetragona	-	67	33	29	10	14	-	-	6	8	11	-	6
Schoenus turbinatus	-	50	8	6	10	-	-	7	-	8	-	-	-
Casuarina monilifera	-	83	33	29	10	-	-	-	-	8	17	-	-
Acacia botrycephala	-	-	67	24	10	14	15	-	-	-	6	21	6
Goodenia ovata	-	-	17	6	20	-	31	7	11	46	33	-	50
Senecio spp.	-	-	8	-	20	-	15	7	33	46	28	17	61
Poa spp.	-	-	17	12	20	14	54	29	61	69	44	100	61
Deyeuxia spp.	-	-	8	12	10	29	8	29	40	-	6	50	11
Pteridium esculentum	-	-	8	18	30	-	62	7	67	-	-	100	100
Casuarina littoralis	-	-	33	71	90	71	38	57	6	-	11	-	-
Astroloma humifusum	-	-	8	29	60	71	38	86	44	-	-	83	6
Helichrysum scorpioides	-	-	8	18	40	-	15	-	-	-	6	17	17
Clematis gentianoides	13	-	-	6	10	57	23	50	-	-	-	-	6
Viola sieberana	-	-	-	18	20	43	-	64	-	-	6	17	-
Bossiaea prostrata	-	-	-	-	30	86	38	86	22	-	-	-	-
Lepidosperma lineare	-	-	-	-	30	43	8	57	6	-	-	-	-
Schoenus apogon	-	-	-	-	-	43	8	100	22	-	11	33	-
Gahnia radula	-	-	-	-	10	57	-	29	17	-	-	17	-
Pultenaea pedunculata	-	-	-	6	-	43	-	21	-	-	-	17	-
Hypericum gramineum	-	-	-	-	-	14	-	57	22	-	-	17	-
Hypochaeris radicata	-	-	8	-	-	-	8	14	100	-	-	-	-
Acaena echinata	-	-	8	-	-	-	15	-	61	-	6	-	-
Gnaphalium spp.	35	-	-	6	40	-	23	36	39	100	-	33	11
Stipa spp.	-	-	-	12	50	43	23	57	33	23	11	17	17
Viola hederacea	-	-	-	6	20	14	62	29	6	8	-	50	22
Danthonia spp.	-	-	-	6	30	71	8	57	39	46	11	100	-
Wahlenbergia spp.	-	-	-	12	20	29	31	50	72	31	11	67	50
Dichondra repens	-	-	-	-	10	-	15	-	56	15	11	67	39
Lomandra longifolia	-	-	-	-	100	86	69	64	67	46	33	67	61
Agrostis spp.	-	-	-	-	10	43	23	57	50	46	11	17	11

TABLE 2 (cont.)

Species	Group 4 n=8	Group 24 n=6	Group 25 n=12	Group 17 n=17	Group 16 n=10	Group 22 n=7	Group 23 n=13	Group 10 n=14	Group 8 n=18	Group 18 n=13	Group 19 n=18	Group 20 n=6	Group 21 n=18
Oxalis corniculata	-	-	-	-	20	29	31	50	94	46	22	67	56
Casuarina stricta	-	-	-	-	20	14	8	21	39	46	28	33	33
Lagenophora stipitata	-	-	-	-	40	43	-	79	17	8	6	17	-
Acrotriche serrulata	-	-	-	-	-	-	8	50	6	-	-	17	-
Anagallis arvensis	-	-	-	-	-	-	-	7	11	38	-	17	-
Gahnia graminifolia	-	-	-	-	-	-	-	29	11	-	6	50	-
Juncus spp.	13	-	-	-	-	-	-	7	17	23	-	50	-
Crassula sieberana	13	-	17	-	10	-	-	-	-	38	6	-	17
Leucopogon parviflorus	-	-	-	47	10	-	15	-	22	-	6	-	22
Scirpus nodosus	-	-	-	-	-	-	15	7	39	54	11	50	17
Acaena novae-zelandiae	13	-	-	-	-	-	15	7	11	8	11	83	17
Sonchus asper	-	-	-	-	-	-	-	-	17	54	11	33	11
Rhagodia baccata	-	-	-	-	-	-	-	-	11	54	22	-	22
Carpobrotus rossii	-	-	-	-	-	-	8	-	22	69	17	-	11
Leucopogon australis	-	-	8	-	-	-	8	-	17	31	28	50	17
Plantago coronopus	-	-	-	-	-	-	-	-	22	15	6	67	-

PLATE 9
Lomandra longifolia open-herbland on dolerite near the south coast being invaded by *Casuarina stricta* four years after the removal of stock from the island. Note the fire-killed trees in the background.

PLATE 10
The high energy granite coast looking west from Cape Sonnerat. Coastal communities dominated by succulents, tussock grasses and *Casuarina stricta* clothe much of the landscape.

Species and Stand Relationships

The species associations shown in the species constellation diagram (fig. 6) largely reflect edaphic variation on the island. The species in the uppermost constellation range from a strong group on the left associated with the peat soils formed on granite colluvium through a group at the top strongly associated with the heaths and scrub on granite to a less strongly defined group on the right which consists of species characteristic of woodland and forest on granite. Some species to the far right occur together over most of the island. The smaller underlying constellation consists of species characteristic of the sandstone and dolerite soils in the western part of the island.

The thirteen major quadrat groupings that resulted from the association analysis form a continuum within which few groups can be recognized by both faithful and constant species (table 2). However the group defined by the absence of all species (19) is the only group which cannot be reasonably defined by the association of two or more constant species. Groups 4, 24, 25 and 17 are almost totally confined to granite and granitic colluvium out of reach of the major influence of saltspray. They form a continuum from the stands in the ill-drained valleys characterized by the presence of *Gymnoschoenus sphaerocephalus* to stands largely in the forests and woodlands of the north characterized by the presence of *Epacris impressa, Banksia marginata* and *Lepidosperma concavum*. Groups 16, 22, 23 and 10 are concentrated in the forests of the west of the island, and the quadrats in the remaining groups are predominantly located in coastal herbland (figure 7). Several floristic regions, most of which include several of the communities defined by both structure and dominance and floristic composition, can be recognized. Group 17 characterizes a large region in the north of the granite part of the island, groups 4, 24 and 25 are intimately mixed in the southern part of the east of the island, groups 10, 16, 22 and 23 characterize the inland dolerite region, groups 19, 20 and 21 dominate the south and east coasts, and group 8 dominates much of the north coast (figure 7).

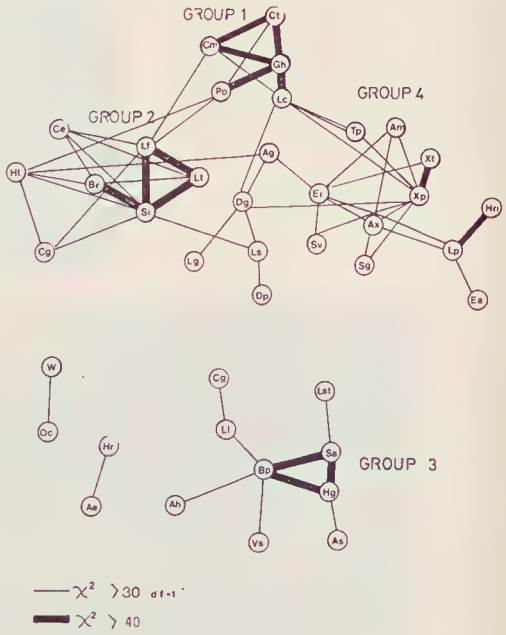

FIG. 6 - Species constellation diagram.
Ae - *Acaena echinata*; Ag - *Acacia genistifolia*; Ah - *Astroloma humifusum*; Am - *Acacia myrtifolia*; As - *Acrotriche serrulata*; Ax - *Amperea xiphoclada*; Bp - *Bossiaea prostrata*; Br - *Bauera rubioides*; Ce - *Empodisma minus*; Cg (group 2) - *Cassytha glabella*; Cg (group 3) - *Clematis gentianoides*; Cm - *Casuarina monilifera*; Ct - *Calytrix tetragona*; Dg - *Dillwynia glaberrima*; Dp - *Drosera pygmaea*; Ea - *Eucalyptus amygdalina*; Ei - *Epacris impressa*; Gh - *Gompholobium heugelii*; Hg - *Hypericum gramineum*; Hr - *Hypochaeris radicata*; Hri - *Hibbertia riparia*; Ht - *Hakea teretifolia*; Lc - *Leucopogon collinus*; Lf - *Lepidosperma filiforme*; Lg - *Leptospermum glaucescens*; Ll - *Lepidosperma lineare* var. *inops*; Lp - *Lepidosperma concavum*; Ls = *Leptospermum scoparium*; Lst - *Lagenophora stipitata*; Lt = *Leptocarpus tenax*; Oc - *Oxalis corniculata*; Po - *Pseudanthus ovalifolius*; Sa - *Schoenus apogon*; Sg - *Stylidium graminifolium*; Si - *Sprengelia incarnata*; Sv - *Spyridium vexilliferum*; Tp - *Tetratheca pilosa*; Vs - *Viola sieberana*; W - *Wahlenbergia* spp.; Xp - *Xanthosia pilosa*; Xt - *Xanthosia tridentata*.

TABLE 3

PERCENTAGE FREQUENCY OF THE DIVINF COMMUNITIES
by geology and position related to coast

Community	SUBSTRATE			LOCATION	
	Sandstone and sand	Dolerite	Granite	Coastal	Non-coastal
4	0	0	100	0	100
24	0	0	100	0	100
25	0	0	100	10	90
17	0	6	94	0	100
16	20	40	40	20	80
22	0	86	14	0	100
23	33	50	17	33	67
10	14	86	0	14	86
8	28	55	17	89	11
18	15	8	77	100	0
19	22	33	45	78	22
20	17	83	-	83	17
21	11	22	66	72	28

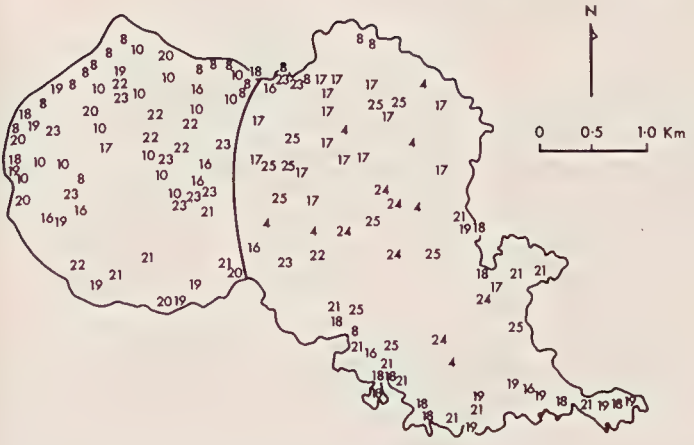

FIG. 7 - The distributions of the communities defined by the DIVINF analysis. See table 2 for the percentage frequency of species within the groups.

Plant-Environmental Relationships

A marked dichotomy exists on Schouten Island between coastal vegetation and inland vegetation. The coastal influence is independent of all other variables, the salt spray communities often transgressing lithological boundaries (table 3). Typical patterns of zonation of the coastal vegetation are shown in figure 4. Zonation is telescoped as exposure to salt-laden winds decreases (plates 1 and 10).

A second dichotomy in the overall vegetation pattern is geological (table 3). The nature of the substrate determines the type and distribution of soil, and nutrient availability and moisture relations differ between soil types.

The major rock types differ markedly. Granite, composed largely of silica and feldspar with a small amount of mica, weathers to form sandy soils which contain fewer of the trace elements, and are therefore, generally less productive than the clayey soils formed from dolerite. Dolerite contains pyroxene and calcic feldspar which, in weathering, release Fe, Mg and Ca ions into the soil (Corbett 1969). Compared with the spatial extent of the two major rock types, sandstone and cover sands are limited in extent and are largely excluded from this discussion.

The constancy of depth of soil on the two major lithologies differs a great deal. The dolerite produces a soil of fairly constant depth and profile, thus giving rise to the fairly uniform covering of vegetation on this substrate. The variation of structural and floristic composition is then accomplished by the influence of other factors, such as firing patterns and variations in moisture availability related to topography. The soil cover on the granite is highly variable in depth from no soil to soils several metres in depth in the poorly-drained colluvium-filled hollows.

Drainage and moisture relations are partly determined by soil type. The dolerite soil has a solid impervious clay base hence runoff on these soils may be fairly rapid. This is borne out by the lack of flowing streams in summer in the west. On the granite, in constrast, moisture is retained in the colluvium-filled hollows and gradual release produces perennial streams. However, moisture availability varies markedly on the granite. On bare rock the runoff is instant. No vascular plants can survive in these situations. At the other extreme the peats formed on the gravels and sands are often water-logged (fig. 4).

Variations in the frequency and intensity of fire may have some considerable effect on the structural variation in the vegetation of the island, and a lesser effect on floristic variation.

The floristic groups on the two main substrata produce distinctive communities which differ in susceptibility to fire intensity and frequency. The heathy nature of much of the vegetation on granite encourages a moderate frequency, moderate intensity fire regime. This is illustrated by the mallee-form of *Eucalyptus amygdalina* growing on the tall open-shrubland complex. Fires are sufficiently frequent to prevent the eucalypt from developing thick enough bark at flame height to avoid crown and stem death. So after each fire the eucalypts are set back to regeneration from buds in lignotubers protected under the ground. Multiple fire boundaries were observed in part of the granite vegetation with as many as four age-height classes in one small area.

The vegetation on the less-insolated slopes on dolerite produces more litter than that on the granite and north-facing slopes on dolerite; and possesses a dense shrub understorey. If fire frequency is low the intensity will be high, resulting in crown death. Such crown fires have occurred immediately east of Crocketts Bay and behind Sarah Ann Bay. In these cases dense shrub regeneration has occurred. These sites are affected by salt spray which might partially explain the death of mature eucalypts. The lack of regeneration may have resulted from a second fire in close succession, followed by grazing and sodium chloride necrosis. On north and northeast facing slopes on dolerite there is a sparse ground cover dominated by graminoids. The relative lack of shrubs may be explained partially by the relative dryness of the insolated slopes combined with the high clay content of the soils, but may also reflect a feedback from dryness to fire frequency and intensity.

Not all Tasmanian vegetation is adapted to fire (Jackson 1968) and even elements in the dry sclerophyll vegetation are susceptible to fire. *Callitris rhomboidea* is one fire susceptible species occurring widely on Schouten Island. *C. rhomboidea* is usually killed by fire, but releases seed that has been held in serotinous cones as a consequence of fire. The species can be thus eliminated by two fires separated by less than the period between seed germination and new seed production, unlike most dry sclerophyll species which recover vegetatively from fire. Some plants that occur with *Callitris* in refuge sites are typical of wet forest areas. The main species in this group are *Pittosporum bicolor, Drimys lanceolata* and *Billardiera longiflora*.

Callitris rhomboidea everywhere occupies niches which are obviously protected from fire. A common locality is in gullies both on the granite and to a lesser degree, on the dolerite. One south-facing slope in a steep gully in the west of the island has a pure grove of *Callitris* trees which have a foothold on a nearly vertical cliff. The clear understorey of this stand presents insufficient fuel for fires severe enough to cause the death of mature *Callitris*. On the granite *Callitris* also occurs among massive boulders which have tumbled into gullies. In a particularly steep gully leading down to Trumpeter Bay there are *Callitris* and *Drimys* trees in profusion. These specimens of *Callitris* are the tallest on the island (approx. 20 m).

Not only inherently fire susceptible species occupy these refugia. On the southwestern slopes of Mt Storey, *Eucalyptus tenuiramis* trees fill the gaps between boulders. These boulders are up to 7 m high and would effectively impede the progress of any fire. The ground cover is sparse, the surface being mainly siliceous gravels, and the tree crowns are more or less even in height with the tops of the boulders.

The ubiquitous fire factor has a modifying influence on the other factors. It has forced certain species into topographically protected sites and has determined the structure of many communities. Floristically the different lithologies produce their own communities but it is fire which moulds their structural expression.

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APPENDIX

HIGHER PLANTS OBSERVED IN THE FREYCINET NATIONAL PARK 1975-1982

Nomenclature follows Curtis (1963, 1967), Curtis and Morris (1975) and Willis (1970) except where authorities are given. + = introduced species.

Abbreviations used: Frey = Freycinet Peninsula; Sch = Schouten Island csl = coastal; for = forest; hth = heath; rk cr = rock crevices; wtld = wetlands

PTERIDOPHYTA

Adiantaceae
Cheilanthes tenuifolia Frey, Sch; for
Pteris tremula Frey; for

Aspidiaceae
Polystichum proliferum Sch; for

Aspleniaceae
Asplenium flabellifolium Frey, Sch; for, hth
A. obtusatum Frey, Sch; csl

Blechnaceae
Blechnum nudum Frey, Sch; for
B. wattsii Tindale Frey, Sch; for
Lastreopsis shepherdii Frey; for

Cyatheaceae
Cyathea australis Frey, Sch; for

Dennstaedtiaceae
Histiopteris incisa Frey, Sch; for, csl
Pteridium esculentum Frey, Sch; hth, for

Dicksoniaceae
Dicksonia antarctica Frey, Sch; for

Gleicheniaceae
Gleichenia dicarpa R.Br. Frey, Sch; hth, for
G. microphylla Frey, Sch; for

Hymenophyllaceae
Hymenophyllum australe Frey; for

Lindsayaceae
Lindsaya linearis Frey; hth, for

Lycopodiaceae
Lycopodium deuterodensum Frey, Sch; hth, for
L. laterale Frey, Sch; hth
L. myrtifolium Forst.f. Frey; rk cr
L. serpentinum Frey; hth

Osmundaceae
Todea barbara Frey; for

Polypodiaceae
Microsorium diversifolium Frey, Sch; for

Schizaeaceae
Schizaea bifida Frey; hth, for
S. fistulosa Frey; hth, for

Selaginellaceae
Selaginella uliginosa Frey, Sch; hth, wtld

SPERMATOPHYTA

GYMNOSPERMAE

Cupressaceae
Callitris rhomboidea Frey, Sch; for

ANGIOSPERMAE

Monocotyledones

Centrolepidaceae
Centrolepis strigosa Frey, Sch; hth, wtld, csl

Cyperaceae
Baumea acuta Frey, Sch; hth, for, wtld
B. arthrophylla (Nees) Boeck. Frey; wtld
B. juncea Frey, Sch; hth, for, wtld
B. tetragona Frey, Sch; wtld
Carex appressa Frey; csl, wtld
C. breviculmis Sch; for
C. iynx Sch; wtld
Caustis pentandra Frey, Sch; hth
Chorizandra cymbaria Frey; wtld
Eleocharis acuta Frey, Sch; wtld
E. sphacelata Frey, Sch; wtld
Gahnia filum Frey; wtld
G. grandis Frey, Sch; for
G. microstachya Frey, Sch; for
G. radula Sch; for, hth
G. trifida Sch; wtld
Gymnoschoenus sphaerocephalus Frey, Sch; hth
Lepidosperma concavum Frey, Sch; hth, for
L. elatius Frey; for
L. filiforme Frey, Sch; hth, for
L. gladiatum Frey, Sch; csl
L. laterale Frey, Sch; for

L. lineare R.Br. var. *inops* (F. Muell. ex Rodw.) Frey, Sch; hth, for
L. longitudinale Frey, Sch; hth, wtld
Schoenus apogon Frey, Sch; hth, for
S. maschalinus Frey; hth
S. nitens Frey, Sch; csl, wtld
S. tenuissimus Frey, Sch; hth
S. tesquorum Frey; wtld
S. turbinatus Frey, Sch; hth
Scirpus cernuus Frey; wtld
S. fluitans Frey; wtld
S. inundatus Frey; wtld
S. nodosus Frey, Sch; csl
Tetraria capillaris Frey, Sch; hth, for

Iridaceae
Diplarrena moraea Frey, Sch; for
Patersonia fragilis Frey, Sch; hth

Juncaceae
Juncus gregiflorus Sch; wtld
J. kraussii Frey, Sch; wtld
J. pallidus Sch; wtld
J. planifolius Sch; wtld
J. procerus Sch; wtld

Juncaginaceae
Triglochin procera Frey, Sch; wtld
T. striata Frey; wtld

Liliaceae
Arthropodium milleflorum Sch; for
Dianella revoluta Frey, Sch; hth, for, csl
D. tasmanica Frey, Sch; for
Drymophila cyanocarpa Frey, Sch; for
Laxmannia sessiliflora Frey; hth
Lomandra longifolia Frey, Sch; hth, for, csl
Stypandra caespitosa Sch; hth
Xanthorrhoea australis Frey; hth, for

Orchidaceae
Acianthus caudatus Frey; hth
A. exsertus Frey; hth, for
A. reniformis Frey; hth
Caladenia angustata Sch; for
C. catenata Frey; hth, for
C. caudata Sch; for
C. deformis Sch; for
C. filamentosa Frey, Sch; for
C. latifolia Sch; csl
C. patersonii Sch; for
C. praecox Sch; for
Chiloglottis reflexa Frey; for
Corybas aconiiflorus Frey; for
C. unguiculatus Frey; hth, for
Cryptostylis subulata Frey; hth
Dendrobium striolatum Frey; for
Dipodium punctatum Frey, Sch; hth, for
Diuris maculata Frey, Sch; hth, for
Eriochilus cucullatus Frey, Sch; hth, for
Gastrodia sesamoides Frey, Sch; for
Glossodia major Frey; for
Lyperanthus suaveolens Frey; for
Microtis sp. Sch; for
Orthoceras strictum Frey; hth, for
Prasophyllum archeri Frey; hth, for
P. australe Frey; hth, for
P. buftonianum Frey; hth
P. elatum Frey, Sch; hth, for
P. nigricans Frey; for
Pterostylis concinna Frey; for
P. curta Sch; for
P. grandiflora Frey; for
P. longifolia Frey; for
P. nana Frey, Sch; hth, for
P. nutans Frey; hth, for
P. parviflora Frey; hth, for
P. pedoglossa Frey; for
P. pedunculata Frey; hth, for
P. plumosa Frey; hth, for
Thelymitra flexuosa Frey; for
T. ixioides Frey; hth, for
T. pauciflora Frey; hth, for

Poaceae
+ *Agropyron repens*
A. scabrum Sch; for
Agrostis aemula Frey, Sch; for
A. avenacea Frey, Sch; for, csl
+ *A. tenuis*
A. venusta Sch; for
+ *Aira caryophyllea*
+ *Ammophila arenaria*
Amphibromus recurvatus Frey; wtld
+ *Arrhenatherum elatius*
+ *Briza minor*
+ *Bromus mollis*
+ *B. sterilis*
+ *B. unioloides*
Danthonia caespitosa Frey, Sch; for, hth
D. geniculata Sch; for
D. purpurascens Sch; for
Deyeuxia monticola Sch; hth
D. parviseta Sch; for
D. quadriseta Sch; hth, for
Dichelachne crinita Frey, Sch; csl
D. sciurea Frey, Sch; hth, for
Distichlis distichophylla Frey, Sch; csl, wtld
Festuca littoralis Frey, Sch; csl
F. plebeia R.Br. Sch; for
+ *Holcus lanatus*
+ *Hordeum leporinum*
Imperata cylindrica Sch; csl
+ *Lolium perenne*
Microlaena stipoides Frey, Sch; for
+ *Monerma cylindrica*
+ *Nardus stricta* L.
Phragmites australis (Cav.) Trin. ex Steud. Frey, Sch; wtld
Poa labillardieri Frey, Sch; for, csl, wtld

P. poiformis Frey, Sch; csl
P. rodwayi Vickery Sch; for
P. sieberana Frey; for
P. tenera Sch; for
+ *Setaria viridis*
Spinifex hirsutus Frey, Sch; csl
Stipa aphylla (Rodway) Townrow Sch; for
S. flavescens Labill. Frey, Sch; csl, for
S. mollis Sch; for
S. nervosa Sch; for
S. pubinodis Trin. and Rupr. Sch; for
S. semibarbata Frey, Sch; hth, for
S. stipoides (Hook) Veldkamp Frey, Sch; csl
S. stuposa Hughes Sch; for
Tetrarrhena acuminata Frey, Sch; for
T. distichophylla Frey, Sch; hth
T. juncea Sch; for
Themeda australis Frey, Sch; hth, for
+ *Vulpia bromoides*
+ *V. myuros*

Potamogetonaceae
Potamogeton tricarinatus Sch; wtld

Restionaceae
*Calorophus elongatus** Frey, Sch; for, hth
Empodisma minus (Hook. f.) Johnson & Cutler Frey, Sch; hth
Hypolaena fastigiata Frey, Sch; hth, for
Leptocarpus brownii Frey, Sch; wtld
L. tenax Frey, Sch; hth
Restio complanatus Frey, Sch; hth
R. monocephalus Labill. Frey; hth

Ruppiaceae
Ruppia maritima Frey; wtld

Xyridaceae
Xyris gracilis R.Br. ssp. *tasmanica* D.I. Morris Frey; hth
X. marginata Rendle Frey, Sch; hth
X. operculata Frey, Sch; hth
X. muelleri Malme Frey; hth

Zanichelliaceae
Lepilaena cylindrocarpa Frey; wtld

Dicotyledones

Apiaceae
Apium prostratum Frey, Sch; csl, wtld
Centella cordifolia Frey; hth, wtld
Daucus glochidiatus Sch; for
Eryngium vesiculosum Frey, Sch; wtld
Hydrocotyle javanica Frey, Sch; for
H. muscosa Frey; wtld
H. pterocarpa Sch; wtld
H. sibthorpioides Frey; csl
Lilaeopsis brownii Frey; wtld
Trachymene anisocarpa Frey; hth
Xanthosia dissecta Frey; hth
X. pilosa Frey, Sch; hth, for
X. pusilla Frey, Sch; hth, for
X. tridentata Frey, Sch; hth, for

Apocynaceae
Alyxia buxifolia Sch; csl
+ *Vinca major*

Asteraceae
Bedfordia linearis Frey; for
B. salicina Sch; for
Brachycome stricta Frey, Sch; for
+ *Carduus tenuiflorus*
Cassinia aculeata Frey, Sch; for
+ *Cirsium vulgare*
Cotula coronopifolia Frey; wtld
C. longipes Frey, Sch; csl, wtld
Craspedia glauca Frey; hth
+ *Gnaphalium candidissimum*
G. involucratum Sch; csl
G. japonicum Thunb. Frey; hth
G. purpureum Sch; csl
Helichrysum apiculatum Frey, Sch; hth, for
H. costatifructum Sch; csl
H. dealbatum Sch; for
H. dendroideum Sch; for
H. obcordatum Frey, Sch; for
H. reticulatum Frey, Sch; csl
H. scorpioides Frey, Sch; hth, for
H. scutellifolium Sch; for
H. semipapposum Sch; for
+ *Hypochaeris radicata*
Ixodia angusta Frey; hth
Lagenophora stipitata Sch; for
+ *Leontodon leysseri*
Leptorhynchos linearis Sch; for
L. squamatus Frey, Sch; hth, for
Microseris scapigera Frey, Sch; for
Olearia argophylla Sch; for
O. ciliata Frey, Sch; hth
O. ericoides Sch; for
O. erubescens Sch; for
O. lirata Sch; for
O. phlogopappa Sch; csl, for
O. ramulosa Frey, Sch; csl
O. viscosa Sch; for
Senecio biserratus Sch; csl
S. hispidulus Frey, Sch; csl, for
S. lautus Sch; csl
S. linearifolius Frey; for
S. quadridentatus Sch; for
+ *Sonchus asper*
+ *Sonchus oleraceus*

Baueraceae
Bauera rubioides Frey, Sch; hth, for

Boraginaceae
Cynoglossum australe Sch; for

C. latifolium Sch; for
Mysotis australis Sch; csl, for

Brassicaceae
Lepidium sp. Sch; csl

Campanulaceae
Wahlenbergia gracilenta Frey, Sch; hth, for
W. quadrifida Sch; for
W. tadgellii Sch; for

Caryophyllaceae
Gypsophila australis Sch; csl
+ *Polycarpon tetraphyllum*
+ *Sagina apetala*
Scleranthus biflorus Frey, Sch; csl
+ *Silene gallica*
Spergularia media Sch; csl
Stellaria flaccida Sch; for
+ *S. media*
S. pungens Sch; for

Casuarinaceae
Casuarina littoralis Frey, Sch; for
C. monilifera Frey, Sch; hth, for
C. stricta Frey, Sch; csl, for

Chenopodiaceae
Atriplex billardieri Frey; csl
A. paludosa Frey; csl
Chenopodium glaucum spp. *ambiguum* Frey; wtld
Hemichroa pentandra Frey; wtld
Rhagodia baccata Frey, Sch; csl
Salicornia blackiana Frey; wtld
S. quinqueflora Frey; wtld, csl

Convolvulaceae
Convolvulus erubescens Sch; for
Dichondra repens Frey, Sch; hth, for, csl
Wilsonia backhousei Frey; wtld

Crassulaceae
Crassula sieberana Frey, Sch; for, hth, csl

Dilleniaceae
Hibbertia acicularis Frey; hth
H. empetrifolia Frey; for
H. fasciculata Frey; hth, for
H. hirsuta Frey; for
H. procumbens Frey; hth, for
H. riparia Frey, Sch; hth, for
H. sericea Frey; hth, csl

Droseraceae
Drosera auriculata Sch; for
D. binata Frey, Sch; hth, wtld
D. gracilis Frey; hth
D. peltata Frey; for
D. pygmaea Frey, Sch; hth, for, wtld
D. planchonii Frey; for
D. spathulata Frey, Sch; hth

Epacridaceae
Acrotriche serrulata Frey, Sch; hth, for
Astroloma humifusum Frey, Sch; hth, for
A. pinifolium Frey; hth, for
Brachyloma ciliatum Frey; hth
B. depressum Frey, Sch; hth, for
Cyathodes divaricata Sch; for
Epacris barbata Frey, Sch; hth
E. impressa Frey, Sch; hth, for
E. lanuginosa Frey, Sch; hth
E. obtusifolia Frey, Sch; hth
E. tasmanica W.M. Curtis Sch; for
Leucopogon australis Sch; hth
L. collinus Frey, Sch; hth, for
L. ericoides Frey, Sch; hth, for
L. parviflorus Frey, Sch; hth, for, csl
L. virgatus Frey; hth
Lissanthe strigosa Sch; for
Monotoca elliptica Frey, Sch; hth, for
M. glauca Frey; for
M. scoparia Frey, Sch; hth, for, csl
M. submutica S.J. Jarman Frey; hth
Pentachondra involucrata Frey, Sch; hth, for
Sprengelia incarnata Frey, Sch; hth, for
Styphelia adscendens Frey, Sch; hth, for

Euphorbiaceae
Amperea xiphoclada Frey, Sch; for, hth
Beyeria viscosa Frey, Sch; for
Phyllanthus australis Sch; hth
Poranthera microphylla Frey, Sch; hth, for
Pseudanthus ovalifolius Frey, Sch; hth

Fabaceae
Aotus ericoides Frey, Sch; hth, for
Bossiaea cinerea Frey, Sch; hth, for
B. prostrata Frey, Sch; hth, for
Daviesia ulicifolia Frey, Sch; for
Dillwynia glaberrima Frey, Sch; hth, for
D. sericea Frey, Sch; hth, for
Glycine clandestina Sch; for
Gompholobium huegelii Frey, Sch; hth, for
Goodia lotifolia Sch; for
Indigofera australis Frey, Sch; for
Kennedia prostrata Frey, Sch; hth, for, csl
+ *Melitotus indica*
Phyllota diffusa Frey; hth, for
Platylobium obtusangulum Sch; for
P. triangulare Frey, Sch; hth, for
Pultenaea daphnoides Frey, Sch; for
P. gunnii Frey, Sch; hth, for
P. juniperina Frey; for
P. pedunculata Sch; for
P. subumbellata Frey, Sch; hth
P. stricta Frey; hth
Sphaerolobium vimineum Frey, Sch; for, hth
+ *Trifolium glomeratum*

+ *Ulex europaeus*
+ *Vicia angustifolia*
+ *V. tetrasperma*

Ficoideae
Carpobrotus rossii Frey, Sch; csl
Disphyma australe Sch; csl
Tetragonia implexicoma Sch; csl

Gentianaceae
Centaurium australe Frey; for
+ *C. pulchellum*
Villarsia reniformis Frey, Sch; wtld

Geraniaceae
Geranium solanderi Sch; for
Pelargonium australe Frey, Sch; csl
P. inodorum Frey, Sch; for, csl

Goodeniaceae
Dampiera stricta Frey, Sch; hth, for
Goodenia humilis Sch; hth
G. lanata Frey, Sch; hth, for
G. ovata Frey, Sch; for, csl
Scaevola hookeri Frey; hth
Selliera radicans Frey, Sch; wtld

Haloragaceae
Gonocarpus humilis Orchard Frey, Sch; hth, for
G. micranthus Thunb. Frey, Sch; hth, wtld
G. tetragynus Labill. Frey, Sch; hth, for
Myriophyllum pedunculatum Frey; wtld

Hypericaceae
Hypericum gramineum Frey, Sch; for

Lamiaceae
+ *Marrubium vulgare*
Prostanthera lasianthos Frey, Sch; for
Westringia angustifolia Frey, Sch; csl

Lauraceae
Cassytha glabella Frey, Sch; hth, for
C. melantha Frey, Sch; for
C. pubescens Frey, Sch; hth, for

Lentibulariaceae
Utricularia dichotoma Frey, Sch; hth, wtld
U. lateriflora Frey, Sch; hth, wtld

Lobeliaceae
Lobelia alata Frey, Sch; csl, wtld
Pratia platycalyx Frey; csl, wtld

Loganiaceae
Mitrasacme pilosa Frey, Sch; hth

Malvaceae
Lawrencia spicata Frey; wtld

Mimosaceae
Acacia botrycephala Frey, Sch; for
A. dealbata Frey, Sch; for
A. genistifolia Frey, Sch; hth, for
A. mearnsii Frey; for
A. melanoxylon Frey, Sch; for
A. mucronata Frey, Sch; for, csl
A. myrtifolia Frey, Sch; hth, for
A. sophorae Frey, Sch; csl
A. suaveolens Frey, Sch; hth, for
A. ulicifolia Frey; for
A. verticillata Frey, Sch; for, csl

Myoporaceae
Myoporum insulare Frey, Sch; csl

Myrtaceae
Baeckea ramosissima Frey, Sch; hth, for
Callistemon pallidus Sch; for
Calytrix tetragona Frey, Sch; hth, for, csl
Eucalyptus amygdalina Frey, Sch; for, hth
E. globulus Frey, Sch; for
E. obliqua Frey, Sch; for
E. ovata Frey, Sch; for
E. pulchella Sch; for
E. tenuiramis Frey, Sch; for
E. viminalis Frey, Sch; for
Kunzea ambigua Frey, Sch; hth, for
Leptospermum glaucescens Frey, Sch; hth, for
L. grandiflorum Frey, Sch; hth, for
L. lanigerum Frey, Sch; hth, for
L. scoparium Frey, Sch; hth, for
Melaleuca gibbosa Frey; hth
M. pustulata Frey; for
M. squamea Frey, Sch; hth
M. squarrosa Sch; hth, for
Thryptomene micrantha Frey; hth, for

Oleaceae
Notelaea ligustrina Sch; for

Onagraceae
Epilobium sp. Frey, Sch; for, wtld

Oxalidaceae
Oxalis corniculata Frey, Sch; for

Pittosporaceae
Billardiera longiflora Frey, Sch; for
B. scandens Sch; for
Bursaria spinosa Frey, Sch; for
Marianthus procumbens Frey, Sch; hth
Pittosporum bicolor Sch; for

Plantaginaceae
+ *Plantago coronopus*
+ *P. lanceolata*

P. varia sensu lato Frey, Sch; for, csl

Polygalaceae
Comesperma calymega Frey, Sch; hth
C. ericinum Frey, Sch; hth
C. retusum Frey; hth
C. volubile Frey, Sch; for

Polygonaceae
Muehlenbeckia adpressa Frey, Sch; csl
+ *Rumex acetosella*
R. brownii Sch; for
+ *Polygonum aviculare*

Primulaceae
+ *Anagallis arvensis*
Samolus repens Frey, Sch; csl, wtld

Proteaceae
Banksia marginata Frey, Sch, hth, for, csl
Conospermum taxifolium Frey, Sch; hth, for
Hakea epiglottis Frey, Sch; hth
H. lissosperma Sch; for
H. nodosa Frey; for
H. rugosa Sch; hth
H. teretifolia Frey, Sch; hth, for
Lomatia tinctoria Frey, Sch; for
Persoonia juniperina Frey, Sch; hth, for

Ranunculaceae
Clematis aristata Sch; for
C. gentianoides Sch; for

Rhamnaceae
Cryptandra amara Frey, Sch; hth
Pomaderris apetala Frey, Sch; for
P. elliptica Frey, Sch; for
P. pilifera Frey, Sch; for
Spyridium eriocephalum Frey; for
S. obovatum Sch; for
S. vexilliferum Frey, Sch; hth, for
Stenanthemum pimeleoides Frey; for

Rosaceae
Acaena echinata Frey, Sch; for
A. novae-zelandiae Frey, Sch; for, csl
+ *Rubus fruticosus* sp. agg.
R. parvifolius Sch; csl

Rubiaceae
Coprosma quadrifida Sch; for
Galium albescens Frey; for
G. sp. Frey, Sch; for
Opercularia varia Frey, Sch; hth, for

Rutaceae
Boronia anemonifolia Frey, Sch; for, csl
B. nana Frey; hth
B. parviflora Frey, Sch; hth
B. pilosa Frey, Sch; hth, for
Correa alba Frey, Sch; csl
C. reflexa Frey, Sch; for
Eriostemon virgatus Frey; hth, for
Phebalium bilobum Frey, Sch; for, hth
Zieria arborescens Frey; for
Z. cytisoides Frey; csl

Santalaceae
Exocarpos cupressiformis Frey, Sch; for
E. strictus Sch; for
Leptomeria drupacea Frey; for

Sapindaceae
Dodonaea viscosa Frey, Sch; for

Scrophulariaceae
Euphrasia collina Frey, Sch; hth
Veronica gracilis Sch; for

Solanaceae
Anthocercis tasmanica Frey, Sch; for
+ *Physalis peruviana*
Solanum laciniatum Sch; for
+ *S. marginatum*
+ *S. nigrum*

Stackhousiaceae
Stackhousia monogyna Frey, Sch; for

Sterculiaceae
Lasiopetalum dasyphyllum Frey, Sch; for

Stylidiaceae
Stylidium graminifolium Frey, Sch; hth, for, csl

Thymeleaceae
Pimelea curviflora Sch; for
P. drupacea Sch; for
P. humilis Frey, Sch; for
P. lindleyana Sch; hth
P. linifolia Frey, Sch; hth, for

Tremandraceae
Tetratheca glandulosa Sch; for
T. pilosa Frey, Sch; hth, for
T. procumbens Frey; hth

Urticaceae
Urtica incisa Sch; for

Violaceae
Viola hederacea Frey, Sch; hth, for, csl
V. sieberana Sch; hth

Winteraceae
Drimys lanceolata Frey, Sch; for

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TIDAL IMMERSION OF THE TAMAR ESTUARY *SPARTINA* MARSH, TASMANIA, AUSTRALIA

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(with two tables, five text-figures and one plate)

ABSTRACT

PRINGLE, A.W., 1982 (31 viii): Tidal immersion of the Tamar Estuary *Spartina* Marsh, Tasmania, Australia. *Pap. Proc. R. Soc. Tasm.*, 116: 143-152. ISSN 0080-4703. Department of Geography, University of Lancaster, Lancaster, England.

The Tamar Estuary, Tasmania, has a tidal regime transitional between semi-diurnal and diurnal with the characteristic tidal sequence being low low, low high, high low, high high. In the mature Rosevears marsh, *Spartina* covers the high tide flat sloping at 0.5° and extends down the upper third of the intertidal slope at 5.0°, to a sharply defined continuous lower limit with only isolated clumps to 0.1 m below.

During 1977 the whole marsh was immersed on all high tides, to a depth between 0.2 and 1.0 m at its upper limit. The lower limit lay at the height of the highest, high low tides but fully emerged on all low, low tides. The upper, middle and lower parts of the marsh were immersed for 1830, 3970 and 6650 hours respectively in 1977. Maximum periods of 23 hours continuous immersion of the lower edge occurred mainly in winter, resulting in non-emergence during daylight hours for up to five consecutive days. The sharp continuous lower limit may result from insufficient light under these conditions to enable buds to form to produce shoots in the following summer. Also, increasing instability in the substrate down the intertidal slope will prevent seedlings and shoots becoming firmly rooted.

INTRODUCTION

The introduction of *Spartina anglica* to the Tamar Estuary, Tasmania, in 1947, indirectly from England, and its subsequent rapid spread along a 29 km stretch of its banks was the subject of an earlier paper (Phillips 1975). *Spartina* colonized a wide variety of rock types and sediments, and slopes which varied between 1° and 28°. Previously the inter-tidal areas had been almost completely bare of vegetation, with only very limited salt marsh development in the innermost parts of the bays, close to high water mark. *Salicornia australis* was the main primary colonizer and the back of this marsh was dominated by *Phragmites*, *Juncus* and *Gahnia*. *Spartina* is now found within the original marsh and extending across the mud flats of the bays towards the main channel of the estuary. It also forms a fringe along the narrower stretches of the estuary. The lower edge of the most mature *Spartina* marsh has a clearly defined continuous lower limit (see plate 1), below which isolated clumps are found only occasionally down to the discontinuous lower limit. The aim of this paper is to examine the tidal relationships of this marsh.

Tidal immersion of *Spartina* has been studied in England (Ranwell *et al.* 1964; Hubbard 1969; Morley 1973), where semi-diurnal tides are experienced, although in the case of Poole Harbour, Dorset, which is the locality of the first two papers, the occurrence of a double high water twice daily modifies the simple curve. The Tamar Estuary experiences a tidal regime transitional between semi-diurnal and diurnal. Dietrich (1963) classifies it as "mixed, predominantly semi- diurnal", whereas the Admiralty (1980) defines it as diurnal but with clearly defined semi-diurnal components.

PLATE 1.- Lower edge of *Spartina* Marsh at Rosevears. High low water on 10 August, 1977 at the lower edge of an isolated clump below the continuous lower limit. The leaves and stems have died back for the winter, and form a straw-coloured thatch over the marsh surface.

TIDAL REGIME OF THE TAMAR

Continuously recording tide gauges are sited at Launceston at the head of the estuary (see figure 1) and 61 km downstream at George Town where it enters Bass Strait. At Rosevears within the central part of the estuary where *Spartina* marsh has developed, there is a tide gauge at which individual observations may be made, although records are not kept. Figure 2 shows the August 1977 tidal curve for Rosevears, which was obtained from tidal predictions for George Town given in the Admiralty Tide Tables, modified to take into account variations between George Town and Rosevears. This reveals the characteristic tidal sequence of low low, low high, high low, high high. It also shows that whilst there is generally only a small difference in height between successive high tides, there is a much greater difference between successive low tides.

Figure 3 shows the curves for two single tidal cycles, the first a spring on 4 August 1977, and the second a neap on 10 August 1977. The curves for George Town and Launceston were taken from the tide gauge charts. That for Rosevears was compiled from observations at the tide gauge there. The short winter hours of daylight prevented the recording of the complete 12½ hour cycle and part of each curve has therefore been extrapolated from the George Town and Launceston records. Comparison of the three curves for each date shows the increase in tidal range from the mouth to the head of the estuary,

producing an increasingly peaked curve towards Launceston. The later time of the tide in the same direction is also indicated, with Rosevears being 55 minutes later and Launceston 1 hour 35 minutes later than George Town on average according to the tidal predictions.

The tides experienced by the *Spartina* marsh are mainly of the type indicated at Rosevears with a small decrease in range affecting the marshes furthest down the estuary towards George Town. The maximum range on spring tides at Rosevears during 1977 was 3.9 m, and the minimum neap range was 2.1 m.

ROSEVEARS EMBAYMENT *SPARTINA* MARSH

A shallow embayment on the west shore of the estuary at Rosevears, close to the tide gauge is one of the oldest *Spartina* marshes of the Tamar (Phillips 1975). A plan and profile of this marsh are shown in figure 4. The initial plantings in the late 1940's and mid-1950's were carried out at Windermere on the east shore opposite and from here it spread rapidly both up-stream and down-stream to occupy the stretch of the estuary indicated on figure 1 by the summer of 1971-72. A series of vertical aerial surveys carried out during the 1960's revealed the details of this spread. At Rosevears *Spartina* was well established in the inner part of the embayment by 1961 and it continued to spread in this area up to 1963, by which time it had appeared also at the southern end. By 1968, *Spartina* had filled the whole embayment to straighten effectively the shore between the adjacent promontories. The straight lower edge of the marsh extended only slightly towards the channel during the following year and a field survey during the 1971-72 summer indicated that no further extension had occurred. A detailed levelling survey in January 1972 showed the height of the upper, landward margin of this marsh to be 3.1 m and the discontinuous lower limit to be 1.2 m above George Town Chart Datum. A further levelling survey carried out five years later in August 1977 showed that no change had taken place in these heights.

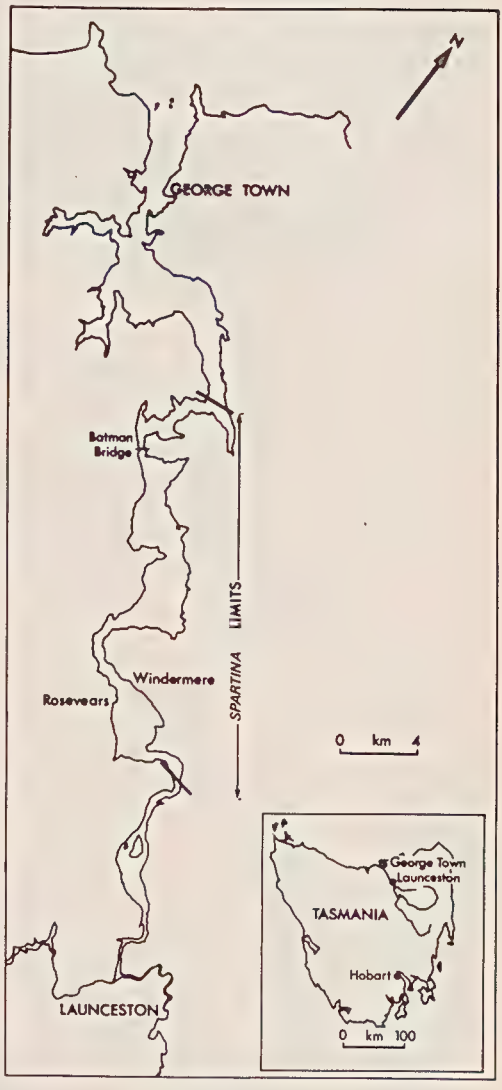


FIG. 1.- Location map.

Because the ground rises abruptly behind the upper margin of the marsh, no extension is possible in this direction. Below the lower edge of the marsh, however, there is an area of bare mud bank exposed down to extreme low water mark. The stable position of this margin since 1969 with its well marked continuous lower limit indicates that some factor or combination of factors is exerting a strong, limiting control.

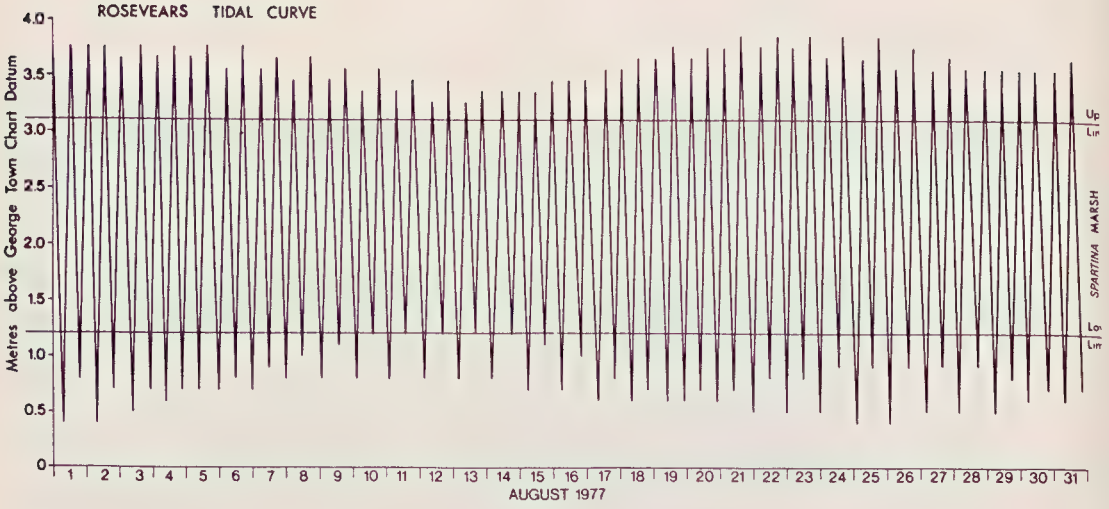


FIG. 2.- Rosevears tidal curve for August 1977. Admiralty tidal predictions for George Town were modified as follows to obtain data for Rosevears:
Times: + 0h 55 min (from Port of Launceston Tidal Predictions for George Town)
Heights: + 0.45 m for high high water and low high water
+ 0.10 m for high low water and low low water (from observations at the Rosevears tide gauge).

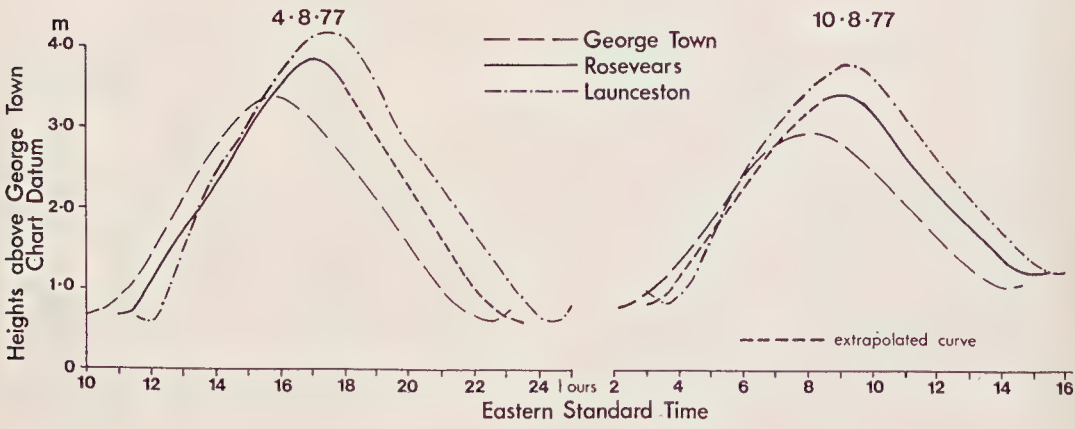
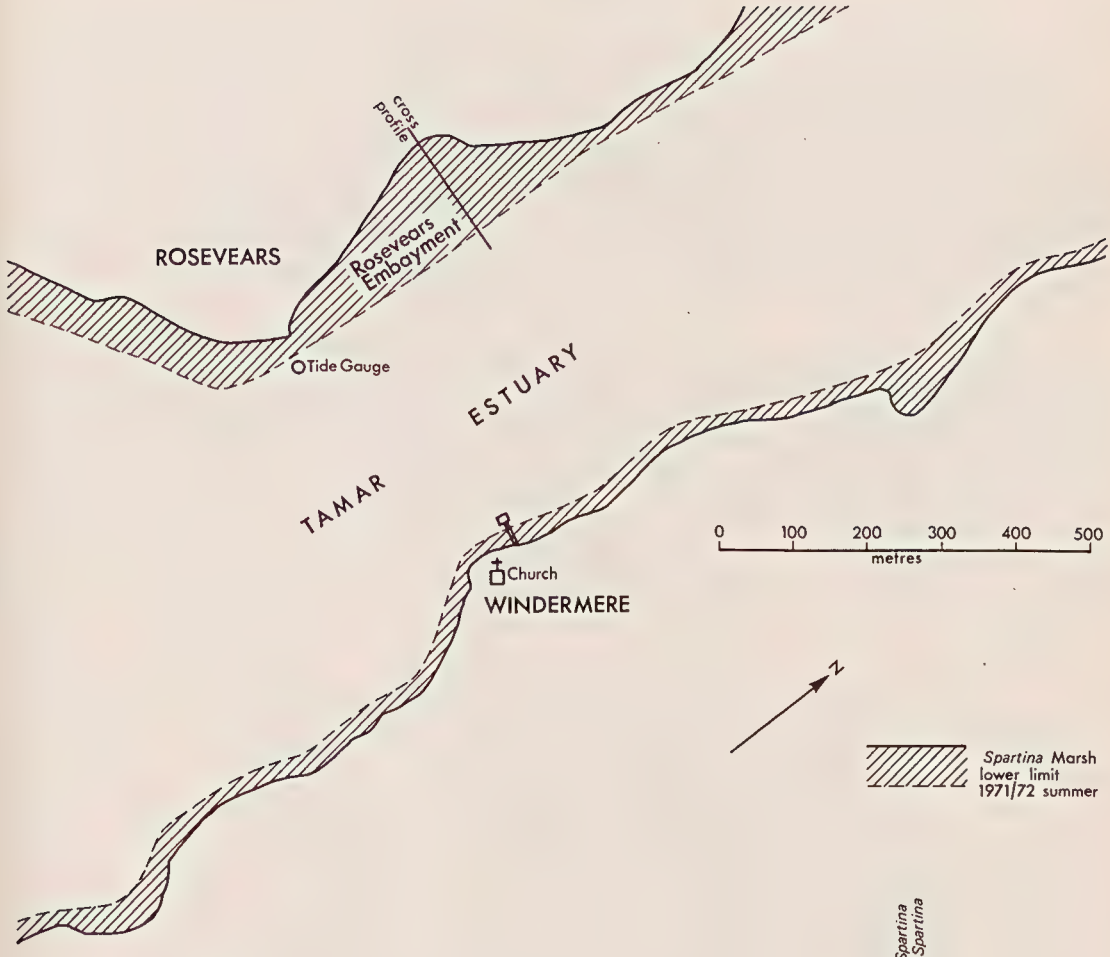
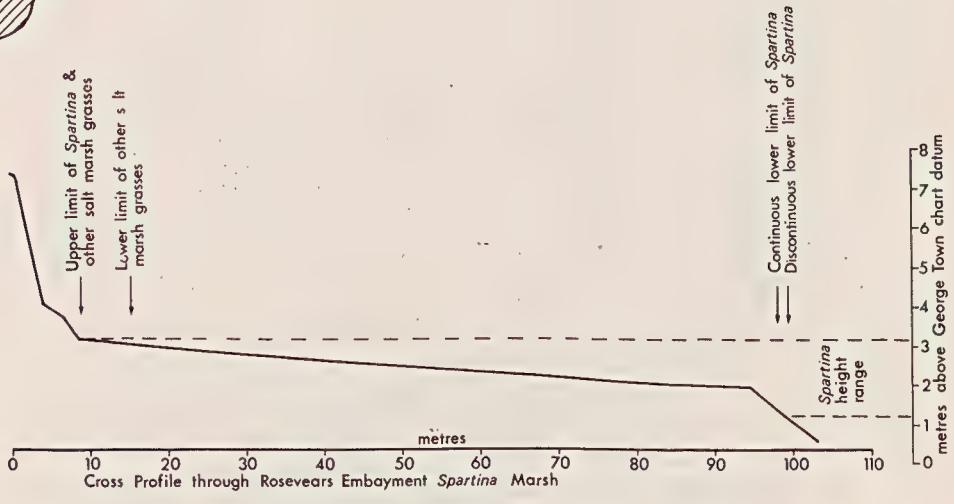


FIG. 3.- Tidal Curves for George Town, Rosevears and Launceston on 4.8.77 and 10.8.77. These were constructed from tidal records, except for the extrapolated sections of the Rosevears curves when darkness prevented recording.


cross profile
ROSEVEARS
Rosevears Embayment
Tide Gauge
ESTUARY
TAMAR
0 100 200 300 400 500
metres
Church
WINDERMERE
N
Spartina Marsh lower limit 1971/72 summer


Upper limit of Spartina & other salt marsh grasses
Lower limit of other salt marsh grasses
Continuous lower limit of Spartina
Discontinuous lower limit of Spartina
Spartina height range
metres above George Town chart datum
0 1 2 3 4 5 6 7 8
metres
0 10 20 30 40 50 60 70 80 90 100 110
Cross Profile through Rosevears Embayment Spartina Marsh

TIDAL RELATIONSHIPS OF THE ROSEVEARS MARSH

Inserted on figure 2, which shows the Rosevears tidal curve for August 1977 are the upper and lower limits of the *Spartina* marsh. These levels refer to the surface of the substrate in which the *Spartina* is growing. During the summer the plants grow to a height of up to 1.5 m above this, but in the winter the leaves and stems die back to produce a lower straw-coloured thatch over the marsh surface as shown in plate 1, and the only living parts, the rhizomes and roots are below the surface of the substrate. Monthly curves similar to that for August have been drawn for the whole of 1977, using the tidal predictions for George Town and making appropriate adjustments for Rosevears as indicated in the caption to figure 2. Details of tidal immersion and emergence of different parts of the marsh become clearly apparent from such diagrams.

Upper edge of the marsh

Table 1 shows the maximum and minimum depths to which the upper edge of the marsh was immersed each month. Especially noteworthy is the fact that the whole marsh was immersed on every high tide during the year, that is it was immersed on both high high and low high tides each day. The minimum depth of immersion, 0.2 m, was reached on between 2 and 6 tides per month during the summer periods of January-February, and November-December, and also during the winter months of August-September. The maximum depth of immersion per month was either 0.8 or 0.9 m except for two very high tides in May which produced a 1.0 m immersion. As the *Spartina* reaches a height of about 1.5 m during the summer growing period the plants here were never totally immersed then.

TABLE 1

TIDAL IMMERSION OF UPPER MARSH EDGE AT HIGH WATER
- ROSEVEARS EMBAYMENT

1977	Maximum depth m	Number of tides	Minimum depth m	Number of tides
January	0.8	3	0.2	6
February	0.8	5	0.2	3
March	0.9	2	0.3	4
April	0.9	8	0.4	12
May	1.0	2	0.4	6
June	0.9	8	0.4	10
July	0.8	14	0.3	5
August	0.8	5	0.2	2
September	0.8	6	0.2	2
October	0.8	8	0.3	11
November	0.9	1	0.2	2
December	0.8	5	0.2	4

Notes: (a) The height of the upper marsh edge in 1977 was 3.1 m George Town Chart Datum.

(b) The maximum depth of submergence with the number of tides producing this, and also the minimum depth of submergence with the number of occurrences was taken from the Rosevears monthly tidal curves, e.g. figure 2 for August 1977.

Lower edge of the marsh

The lower edge of the Rosevears marsh emerged at all low low tides. Table 2 shows the minimum emergence per month at high, low tides. Only during the four months of February, March, September and October was there complete emergence. During May, June and July the highest, high low tides did not fall below the continuous lower limit at 1.3 m, George Town C.D., on between 3 and 5 tides per month, thus leaving the scattered, isolated *Spartina* clumps below it immersed between successive low low tides. During these winter months when the leaves and stems are dead the only living parts of the plant are below the surface of the substrate and are thus totally immersed on such tides. During the remaining 5 months of January, April, August, November and December the highest high low tides fell to the outer edge of the isolated clumps, the discontinuous lower limit, at 1.2 m George Town C.D., on between 3 and 5 tides per month; and this was the case also on 2 or 3 tides during each of the months of May, June and July. Plate 1 shows high low water in this position on 10 August 1977.

The periods when these highest, high low waters occurred were mainly during the winter months of April to August, but some also occurred during the summer in January and November-December. It does appear that there is a close relationship between the height of these highest, high low tides and the lowest level to which the *Spartina* marsh is able to develop.

TABLE 2

MINIMUM TIDAL EMERGENCE OF LOWER MARSH EDGE AT HIGH LOW WATER - ROSEVEARS EMBAYMENT

1977	
January	4 tides at discontinuous lower limit
February	complete emergence on all tides
March	complete emergence on all tides
April	3 tides at discontinuous lower limit
May	3 tides at discontinuous lower limit; 4 tides at continuous lower limit
June	2 tides at discontinuous lower limit; 5 tides at continuous lower limit
July	3 tides at discontinuous lower limit; 3 tides at continuous lower limit
August	5 tides at discontinuous lower limit
September	complete emergence on all tides
October	complete emergence on all tides
November	3 tides at discontinuous lower limit
December	4 tides at discontinuous lower limit

Notes: (a) The continuous lower limit is the clearly defined lower edge of the mature *Spartina* marsh at a height of 1.3 m George Town Chart Datum, in 1977.

(b) The discontinuous lower limit encompasses the few isolated *Spartina* clumps below the continuous lower limit and was at a height of 1.2 m George Town Chart Datum, in 1977.

(c) The number of high low waters at the continuous lower limit, at the discontinuous lower limit, and below the latter was taken from the Rosevears monthly tidal curves, e.g. figure 2 for August 1977.

Duration of tidal immersion

The absence of continuous tide gauge records for the central part of the Tamar estuary, where the *Spartina* marsh has developed, means that precise measurements of lengths of time of tidal immersion are not possible. The tidal records for George Town for the first two weeks of March and August 1977 were used to produce approximate extrapolated curves for Rosevears from which the immersion times of different parts of the marsh were calculated. The same periods of the monthly curves for George Town were then fitted to the remainder of the 1977 monthly curves. This enabled the calculation of immersion times at Rosevears to be extended throughout 1977.

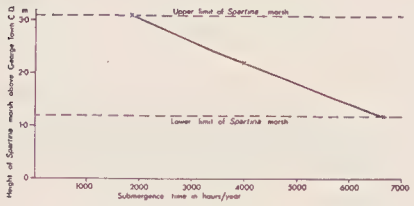


FIG. 5.- Duration of tidal immersion of Rosevears *Spartina* marsh in 1977. The times relate to the immersion of the surface of the substrate, which is the upper limit of the living parts of the plants during the winter months. During the summer growing season the leaves, stems and flowers will reach up to 1.5 m above this.

The upper edge of the marsh was immersed for a total of approximately 1830 hours, the middle for 3970 hours and the lower edge for 6650 hours during 1977 (see figure 5). The average lengths of immersion per tidal cycle for the combined periods of 1-14 March and 2-14 August were 2.6 hours (range 1-4 hours), 5.6 hours (4.5-6.5) and 9.2 hours (8.25-22) for the upper, middle and lower marsh respectively. The maximum period of continuous immersion of the extreme lower edge during the highest high low waters of 1.3 m on neap tides was approximately 23 hours out of the diurnal cycle of 25 hours. As the brief periods of emergence (with only one exception) occurred during the hours of darkness in the winter months of May, June and July, the isolated clumps of *Spartina* forming the extreme lower fringe of the marsh did not emerge during the daylight hours on three consecutive days in May and July and five consecutive days in June.

DISCUSSION

The presence in the Tamar Estuary of extensive areas of previously bare inter-tidal mud flats and the particular tidal regime described, clearly provided an ideal ecological niche for the introduction of the exotic species *Spartina anglica*. Its rapid spread, usually from an initial position close to high water mark, appears to meet no barrier in its advance towards the main channel of the estuary until it reaches the level of the highest high low tides.

Davies (1980) divided the morphology of tidal flats in coastal inlets into the high tide flat below which lies the intertidal slope. The high tide flat is relatively stable and vegetated whilst the intertidal slope is characterized by considerable instability with alternate deposition and erosion creating conditions generally unfavourable to plant growth. The junction between the two slope elements is convex. These morphological elements can be seen clearly in the Rosevears marsh profile (figure 4) with the high tide flat sloping at only 0.5° whereas the angle of the intertidal slope is 5.0°. *Spartina* grows to the upper margin of the high tide flat and almost certainly would be capable of growing at a higher level in relation to High Water Mark, as the entire marsh is immersed on all high tides and is under a considerable depth of water at spring tides. However the *Spartina* is prevented from spreading landwards by the steeply rising ground, already colonized by fresh-water vegetation. Rapid accretion by sedimentation did occur on the high tide flat during the earlier stages of *Spartina* colonization and this was shown by the presence of *Spartina* remains to a depth of 2.29 m beneath the surface in 1972 (Phillips 1975). However there was no evidence of accretion continuing between 1972 and 1977. The main source of sediment for the earlier accretion was probably the extensive mud flats of Nelsons Shoal upstream from Windermere which by the early 1970's was

colonized by the largest continuing area of *Spartina* in the Tamar Estuary thus effectively trapping the previously more mobile sediment.

The lower limit of *Spartina* growth does not coincide with the clearly defined convex junction between the high tide flat and the intertidal slope, but is over a third of the way down the intertidal slope towards its lower boundary at Low Low Water Spring Tide Mark, the extreme level of which was 0.1 m George Town Chart Datum in 1977. The position of the convex slope junction is generally controlled by sedimentation and channel regimes and it appears therefore that there is some other factor or combination of factors controlling the lower limit of *Spartina*. The fact that this lower limit coincides with the height of the highest, high low tides may point to a significant relationship. As Hubbard stated the tidal immersion of a marsh may alter many of the environmental conditions within the habitat, including moisture content, salinity, aeration, light intensity and duration, and temperature. It also produces such physical changes as intermittently present wave and current action.

The closest comparable published data on a *Spartina* marsh is that relating to Poole Harbour, Dorset. Ranwell *et al.* (1964) gave the tidal immersion limit there for *Spartina* as 5800 hours/year which is 87% of the annual immersion time of 6650 hours for the lower edge of the Rosevears marsh. Hubbard (1969) after inspecting a year's tide gauge records from Poole Bridge, determined that on the highest low water on a neap tide in November the lowest level of the Poole Harbour marsh was continuously immersed for 23½ hours. This is similar to the figure for the Rosevears marsh on the highest high low waters between May and July. As buds developing in November produce shoots for the following summer growing season, Hubbard suggested that the amount of light reaching *Spartina* at this time of year is critical for its survival. This may be the reason for the lower limit of the Rosevears *Spartina* at a level where several consecutive days with no daylight emergence are experienced during the equivalent southern hemisphere month of May and the two subsequent months.

As there is very little cliffing along the continuous lower limit of the Tamar marshes and as only very small waves are able to develop in the narrow confines of the estuary it does not appear that exposure to wave attack limits their lower extension. The lowest edge of these marshes is closest to the main channel in which the tidal streams reach their maximum velocities. Sedimentary conditions on the adjacent parts of the inter-tidal slopes become increasingly unstable towards the channel and this may be a further limiting factor, preventing seedlings and shoots becoming firmly rooted. The sharpness of the continuous lower limit probably results from the steepness of the intertidal slope and therefore the rapidity of change in the length of tidal inundation which itself influences the wide range of environmental conditions referred to.

ACKNOWLEDGEMENTS

Helpful criticism by and discussion with Professor J.L. Davies, School of Earth Sciences, Macquarie University, Sydney, Australia, are gratefully acknowledged. Thanks are also due to the Geography Department, University of Tasmania for the loan of equipment for field work.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 116, 1982.

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TEMPORAL AND SPATIAL DISTRIBUTION OF THE TASMANIAN DEVIL, *SARCOPHILUS HARRISI* (DASYURIDAE:MARSUPIALIA)

by Eric R. Guiler,
Department of Zoology, University of Tasmania.

(with two text-figures and two tables)

ABSTRACT

GUILER, E.R., 1982 (31 viii): Temporal and spatial distribution of the Tasmanian Devil, *Sarcophilus harrisi* (Dasyuridae: Marsupialia). *Pap. Proc. R. Soc. Tasm.*, 116: 153-163. ISSN 0080-4703. Department of Zoology, University of Tasmania, Hobart, Tasmania.

The Tasmanian devil *Sarcophilus harrisi* (Boitard), once widespread on continental Australia, probably became extinct there partly due to food competition with dingoes and, possibly, black man and their extinction may have been expedited by a dry climatic change before white man's appearances. Recent reports of wild devils on the continent must be regarded as very doubtful. Devils now are widespread and numerous in Tasmania and have suffered at least one major population cycle since white occupation. The species appears to live well in competition with man.

INTRODUCTION

The Tasmanian devil, *Sarcophilus harrisi* (Boitard), is the largest marsupial carnivore surviving in substantial numbers and since the arrival of white settlers in Australia in 1795 has been known in the wild state only from Tasmania. However, fossil and sub-fossil remains are widely known from continental Australia and it seems appropriate to review information on their past and present distribution and to record the distribution and numbers of the Tasmanian population of *Sarcophilus*.

SPATIAL DISTRIBUTION ON CONTINENTAL AUSTRALIA

A fossil species of *Sarcophilus*, *S. laniarius* Owen, described from Australia was considered by Stephenson (1963) to be synonymous with *S. harrisi*. However, Ride (1964) separated *S. laniarius* and *S. harrisi* statistically but Archer's (1977) results suggest a size continuity in the Late Pleistocene and modern devil populations which supports Stephenson's views. Horton (1977) described a very small fossil devil from the Holocene of Cape York which may be another species. A further fossil species, *S. prior* de Vis, was shown by Bartholomai and Marshall (1973) to be not a member of the Dasyuridae but assignable to *Vombatus*. However, fossil and sub-fossil remains of *S. harrisi* have been found widely in deposits, mainly cave and dune, on the continent of Australia and it is these that provide the distributional data for this study.

Victorian records summarized by Gill (1953) and added to by Wakefield (1964) show that *Sarcophilus* formerly lived in that State, Gill commenting that it was once widely distributed over the Victorian plains. The southern range of the species extended into South Australia (Hale and Tindale 1930; Mulvaney *et al.* 1964) and across the Nullabor into Western Australia (Glauert 1914; Cook 1960, 1963a, b; Lundelius 1963).

Devils were first reported from New South Wales by Owen (1877) and Calaby and White (1967) further enlarged the range to the Northern Territory so that it is now clear that devils were once over most, if not all, of continental Australia, although it is not known whether they were ever present in central Australia. The records suggest that devils may have been confined to the damper coastal regions as well as the mountain ranges where moisture and shade could be found.

Certain islands off southern Australia have supported former populations of devils, Calaby and White recording remains from Kangaroo Island, whilst Hope (1973) reported sub-fossil remains from Flinders Island. Their presence on Flinders Island might be expected in view of the land bridge across Bass Strait which connected this island with Tasmania and Australia until about 22 500-12 750 years ago (Rawlinson 1974). Their occurrence on Kangaroo Island indicates that devil populations were isolated on other islands connected to the mainland as well. *Sarcophilus* has not been reported from King Island.

The remains of *Sarcophilus* often are associated with or in the same geographical area as those of *Thylacinus cynocephalus* (Lowry and Lowry 1967). In view of the association of these remains it is of interest to note that *Thylacinus* has been reported from New Guinea (van Deusen 1963) so it is possible that *Sarcophilus* may well be discovered there in the future.

TEMPORAL DISTRIBUTION ON CONTINENTAL AUSTRALIA

The more recently discovered deposits from which *Sarcophilus* remains have been identified have been dated by radio-carbon methods and appear to have an age of between 1 300 and 3 800 B.P. which is contemporaneous with fossil thylacine remains from Western Australia (Mulvaney *et al.* 1964; Partridge 1967). However, Gill (1953) reported a date of only 538 ± 200 years for a Victorian site but later corrected this when more accurate techniques yielded a date of 5 000 B.P. (Gill 1971), which is more in keeping with other datings. Lundelius (1963) found devil bones in a Western Australian cave which were accompanied by bones of the introduced rabbit and mouse, but the latter probably were intrusive. Butler (1969) found *Sarcophilus* bones in a Western Australian dune deposit which were associated with both rabbit and fox bones. Dune deposits are unstable and this report may not mean much in chronological terms. It is also unlikely that the other rabbit-devil association is strictly contemporaneous since the invasion of Western Australia by rabbits did not occur until 1894 and they did not reach the coast (at Geraldton) until 1907 (Ratcliffe 1959). Thus if the devils occurred with the rabbits it would have been well within the period of white settlement but there is no record of devils having been seen or believed to have lived there during this time.

Live devils have been captured rarely from continental Australia, mainly from Victoria. Kershaw (1912) recorded a live devil from Tooborac, about 100 km from Melbourne and in spite of considerable efforts was unable to determine whether or not this animal had escaped from captivity. *Sarcophilus* was then an unprotected species and records of exports to mainland zoos or circuses were not kept. He also went on to record *Sarcophilus* bones from the shores of Lake Corangamite (also Victoria) and stated that the bones were unmineralized and had the appearance of being fresh. A further devil was caught in Victoria near Ballarat on 22 May, 1971 but this was believed to be an escaped animal (*The Mercury* 1971). One escapee lived on the Melbourne waterfront docks for some time in the 1960-1965 period.

It would appear from these records that escaped animals can survive for at least some time in the wild in Victoria and it would not be unreasonable to expect them to be successful there since the climate and other conditions there closely resemble those in northern Tasmania.

SPATIAL DISTRIBUTION IN TASMANIA

Early diarists write of devils being found around the camps during the period of the settlement of Hobart and it can be inferred that devils were widespread in Tasmania at that time, but details of numbers are lacking. Stock station records about this time mention only rarely devils in northwestern Tasmania, only one lamb being reported killed by devils at Surrey Hills (Van Diemen's Land Coy 1838) whilst many lambs as well as sheep were killed by dogs, thylacines, vagabonds and aboriginals.

The first evidence on numbers of devils is contained in Meredith (1850) who reported that they were very numerous on the east coast, 143 being caught at Apsley in the course

of one winter. Gunn (1852) gave no information on the distribution or numbers of *Sarcophilus* but Gould (1863) noted that they were scarce in cultivated areas and were abundant in the "rougher places", but he did not give any indication of a diminution or increase in numbers since Meredith's time.

Lucas and Le Soeuf (1909) largely repeated Gould's comment without any further evaluation of the numbers but Smith (1909) did not find any devils at the Magnet Mine which is situated in an area which surely would be classed as a "rough place". The observations of Smith which were based on field work were supported by those of Flynn (1911) who could find only one female upon which to base his description of the female reproductive system and it is evident that the status of devils had altered and that they were uncommon or even scarce at that time. Lord (1919) noted that devils were in the rougher parts of the State but Flynn (1923) considered that *Sarcophilus* was a disappearing species. Later Lord (1928) reiterated his earlier statement and went on to say that there was every prospect of devils remaining in the more remote parts of the State for some time. It is clear that there was a difference of opinion regarding the status of devils at this time but there does seem to be a rather repetitious use of Gould's "confined to the rougher parts". However, we can be certain that devils were not common in the settled areas, if in fact they occurred there at all.

Lord and Scott (1945) repeated Lord's earlier opinion but qualified it by stating that devils were more abundant than was apparent as few people were in the parts of the country inhabited by them. Fleay (1946) captured 19 devils in the Jane River-Raglan Ranges area in November, 1945 and 10 in March, 1946. The many snares set together with the attractive live and dead bait used in the traps by this expedition during the five months they operated in the area might have been expected to have yielded more devils than were actually caught had they been abundant. It should be noted that at the present time of devil abundance (1977) this area does not support large numbers of devils nor would it be reasonably expected to, especially in view of the results obtained by Hocking *et al.* (1978). At about this time devils were not known in some cultivated areas, a specimen captured in Turners Marsh in 1954 could not be identified in the locality and was sent to the Queen Victoria Museum for identification. Apparently, devils were so uncommon that the public were unaware of their existence or even of their appearance.

Kimberley (1973) collected observations from the owners of "Glenconnel" and "Auburn" properties near Ross and recorded that devils were very unusual in that area in 1946 and their capture was worthy of comment but by 1953 more were being sighted. The number of devils continued to increase in rural areas, so much so that the first complaints about devil numbers and the damage they allegedly caused to livestock came from Kentish Council in 1960 (Guiler 1960; Cox 1961) as well as from Cape Portland and adjoining Icena. In 1964 damage complaints were received from Smithton (Ablitt 1964) and an expedition in that area in 1963-4 substantiated this claim by capturing a number of devils (Guiler 1966).

Since that time newspaper reports spoke of devils in places where they had been unknown for many years, even reaching Hobart suburbs (*The Mercury* 1974). Devil tracks have been seen intermittently on Mount Nelson since 1968 although the animals have not been sighted.

Although devils were common in various places, especially in northeastern Tasmania, they were still sufficiently unusual in other parts of the State for their presence to be specially reported, McIntyre (1961, 1963) recording them from Woolnorth and Georgetown, Hanlon (1962) sighted them at Mt Picton, and Hooper (1962) on the Coles Bay Road.

The alleged depredations by devils led landowners to apply for permits to destroy them, the first being issued on Cape Portland in August 1960 followed by other permits in 1966 (Table 1). In addition to those listed in the table permits also were issued to Bonneys Plains (1974); Avoca (1974); Cullenswood (1976); Ormley and Royal George (1975); Beaufront (1974); Deddington (1973, 1974); Conara (1973, 1976); Blessington (1974, 1975); Lake Leake (1975, 1976); Mt Morriston (1976); Buckland (1974); Kingston (1974); Carlton

(1975); Georgetown (1975); Relbia (1976); Nunamara (1973); Turners Marsh (1974) (fig. 1). The latter record is of particular interest since it was at this place 21 years earlier that no person in the district could identify a devil.

TABLE 1

SOME PERMITS ISSUED FOR THE DESTRUCTION OF *SARCOPHILUS HARRISI*.
Only those properties which frequently receive permits are shown.

Property	Date	Observations
Cape Portland	8/1960	More than 70 taken
	7-8/1966	More than 134 taken
	7/1969	More than 51 taken
	10/1973	
Icena	7/1966	130 taken
	8/1966	40 taken
	11/1966	10 taken
	9/1968	52 taken
	7/1969	Issued to Rushy Lagoon
	8/1969	31 taken
Auburn	3/1968	
	1-2/1973	94 taken
	2-4/1973	198 taken
	2/1975	
	4/1975	
	7/1975	
	2/1976	
Glenconnel	2-4/1973	40 taken
	8-10/1975	
	1/1976	
Nile	7/1968	11 taken
	8/1969	17 taken
Cressy	-/1965	
	-/1972	
	-/1975	
	-/1976	

No particular distribution pattern can be derived from the above information although it can be concluded that devils are widespread and numerous at the present time throughout the central and northeastern agricultural districts of the State. They are undoubtedly common in other parts of the State, devils having been trapped by the Zoology Department workers at Glen Huon; Friendly Beaches; Greens Creek; Woolnorth; Uxbridge; Interlaken; Silver Plains; Lake St Clair area. Road kills and sightings from many parts of Tasmania over the past five years have confirmed this widespread distribution although devils apparently are not common in the rainforest and wet sclerophyll forests of the western parts of the State. A survey carried out in this area by Hocking *et al*. (1978) found that devils were scarce in the area.

NUMBERS

The evidence presented above shows that there has been an increase in the numbers of devils in Tasmania over the last 25 years. Devils foraging habits have brought them into conflict with farming activities (Guiler 1970a). The depredations can readily be identified and farmers apply for permits to control devil numbers on troubled properties.

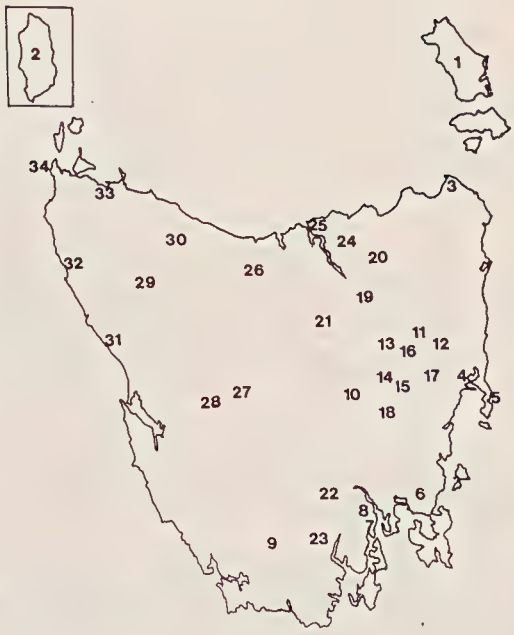

FIG.1- Outline map of Tasmania showing places mentioned in the text. Apsley - 4; Auburn - 14; Avoca - 11; Beaufront - 15; Blessington - 17; Bonneys Plains - 11; Buckland - 6; Cape Portland - 3; Carlton - 6; Coles Bay - 5; Conara - 13; Cressy - 21; Cullenswood - 12; Deddington - 16; Flinders Is. - 1; Friendly Beaches - 5; Georgetown - 25; Glenconnel - 14; Glen Huon - 23; Granville - 31; Greens Creek - 32; Icena - 3; Interlaken - 10; Jane River - 28; Kentish - 26; King Is. - 2; Kingston - 7; Lake Leake - 17; Lake St Clair - 27; Magnet Mine - 29; Mount Morriston - 18; Mount Nelson - 8; Mount Picton - 9; Nile - 16; Nunamara - 20; Ormley - 11; Raglan Ranges - 28; Relbia - 19; Royal George - 12; Smithton - 33; Surrey Hills - 30; Turners Marsh - 24; Uxbridge - 22; Woolnorth - 34.

The number of devil control permits issued has increased and may be taken as an indication of the impact that these animals are having upon farming properties. Devils are now to be encountered in most parts of the State, especially those which have some farming activity.

Guiler (1970b) estimated the numbers in the devil population at Cape Portland after a two-year investigation to be 136 and the numbers at Granville Harbour were found to range from 14 to 107 over the period 1966-1975, reaching a peak of 107 in 1975 and a minimum of 13 in 1978 (Guiler 1978). Guiler concluded that the Granville population reached a maximum some time after the populations in some other parts of the State such as Cape Portland and Icena where a peak was reached in 1966-69 and the Nile where a peak was attained in 1968-69. No other population estimates have been made except Kimberley's (1973) count of devils taken under permit at the Auburn and Glenconnel properties when 195 animals were taken during a trapping programme which reduced the population almost to local extinction.

Care has to be taken in interpreting the catch per trap per night as an index of relative abundance of devils. It has been shown at Cape Portland that the catch per trap per night declines during a lengthy period of trapping as in 1966 when the catch was 0.366 in May and dropped to 0.064 in October although the number of devils in the area was about the same (Guiler 1970b). However, field returns from Granville show that over a short term the number of animals caught reaches a maximum after three or four nights and then declines. The Granville work was undertaken in short "bursts" to allow for this.

However, if devils are trapped over very short periods and at long intervals of time this trap shyness can be reduced and the catch/trap/night used as an index of relative abundance (fig. 2). This yield of devils reached a peak in 1973-75 with indices from 0.226 to 0.273. Previous to this the indices for 1966-72 (inclusive) varied about a mean of 0.129. Subsequent to 1975 the index dropped very markedly to a mean of 0.065. It may be interpreted that the devil population was fairly stable over the period 1966-70 then rapidly increased in 1973, peaking in 1975 and decreasing rapidly in 1976. This conclusion

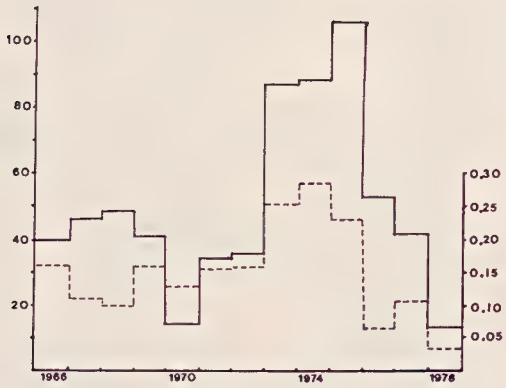

FIG.2- Histograms of the catch of devils per trap per night at Granville, 1966-78, and of total estimated population (solid line). Based on data in Guiler (1978).

is supported by further field evidence such as footprints, droppings and activity around carcases as well as the trapping results.

The catch does vary from locality to locality as Granville in 1974 yielded 0.421 animals/trap/night; Auburn, 1973 produced 0.102 animals and Friendly Beaches in 1975 gave 0.083 animals. It is known that the population at Cape Portland was more dense than that at Granville and it is clear that the characteristics of each region and its population affect catches, such as availability of food, reproductive status of the females, familiarity of the animals with the traps, trap setting in relation to areas of devil activity, local movement patterns, weather and season.

TABLE 2

CATCH PER TRAP PER NIGHT FOR TASMANIAN DEVILS AT GRANVILLE 1966-78.
The population was estimated by the Petersen Index.

	Number of traps	Catch/trap	Estimated population
1966	396	0.157	40
1967	586	0.111	46
1968	331	0.093	48
1969	778	0.116	41
1970	233	0.124	14
1971	244	0.151	34
1972	296	0.152	36
1973	726	0.248	87
1974	1021	0.273	89
1975	522	0.226	107
1976	678	0.064	52
1977	435	0.092	42
1978	328	0.039	13

DISCUSSION

Tasmanian devils were once widespread, if not common, over much of continental Australia and the problem of their present restriction to Tasmania should be viewed in relation to their disappearance from the continent rather than seeking reasons why they survived in Tasmania. The climate of Australia in the Late Pleistocene was colder than at present with glaciation in Tasmania and on the Snowy Mountains between 25 000-15 000 years ago, but the climate warmed up from 15 000-10 000 years ago. In the last 10 000 years the climate has been relatively stable but with a period of higher rainfall and warmer conditions between 9 000-6 000 years ago (Bowler *et al.* 1976). It is this latter period that is of concern to this discussion.

The more moist climate some 6 000-9 000 years ago would have suited devils more than the present arid conditions. The climate has changed little since devils have been established as living on continental Australia, say 3 000 B.P. The environment found in some parts of Australia, for example some of the gullies of the eastern mountains of New South Wales and Victoria would appear to offer very suitable habitat for devils, little differing from that which they use extensively in northeastern Tasmania and it is difficult to believe that climatic alterations are responsible for their extinction on Australia. It has been shown that *Sarcophilus* is a competent thermoregulator (Hulbert and Rose 1972; Guiler and Heddle 1974) and it would be capable of living in much of the present Australian environment. Gill (1953) favoured the concept of devils preferring colder climates but their efficient thermoregulation together with the strictly nocturnal habits would permit them to use warmer situations.

Thus, the climate of 6 000 years ago would have suited devils but the drier conditions of the last 5 000 years would not have been sufficiently drastic to have caused the total disappearance of *Sarcophilus* from continental Australia and we must look to other factors such as interspecific competition. The species with which the devil would have competed, either directly or indirectly, are black man, white man, black man's dog and dingoes. Of these three we can eliminate white man as there is no evidence of live devils living in Australia at the time of white settlement.

Sarcophilus occurred on what is now Flinders Island using the land bridge through this area. The species has never been reported alive from the Island (Hope 1973) so that devils must have been extinct there by 1800, probably very much earlier than this. This is of some interest as the introductions which usually are named as interspecific competitors with *Sarcophilus*, the dingo and the fox, have never been found in the Furneaux Group. Food on Flinders Island for a scavenging species such as *Sarcophilus* would have become less abundant as the seas rose and isolated the island and the available sources were not able to sustain a viable devil population. This situation would have been accentuated by the nature of the vegetation of the island in its undeveloped state which was mainly thick forest or scrub which was unlikely to carry much suitable prey.

There is dispute over the date of invasion of Australia by dingoes. Rolls (1969) believed that the dingo came to Australia with aboriginal man, and therefore entered active competition with the devil, about 7 000 years ago. Macintosh (1975) agreed that dingoes did not appear in Australia before 8 000 B.P. and showed that dingoes did not occur in the archaeological context until 3 000 B.P. Assuming these dates of introduction to be correct, then the dingo would have had the advantage of wetter and warmer conditions to expedite its colonization and spread across Australia. Macintosh (1975) went on to suggest that devils were extinct by 3 000 B.P. and deduced that dingoes and devils never were in competition. These dates are not supported by the datings of Mulvaney *et al.*'s (1964) materials.

It is difficult to accept the extinction of the Australian devils as being caused only by direct competition with black man and canids, be they dogs or dingoes. There are many areas with permanent water, and dense vegetation which would offer shelter to devils and where dingoes could not operate successfully. The climate of southeastern Australia offers much the same conditions as northeastern Tasmania where devils abound, and it could be

expected that devils would thrive there if they were introduced. It may be that the combination of competition and climatic alternatives was sufficient to cause their decline but I feel that some other presently unknown factor or factors may have contributed.

It is clear that *Sarcophilus* whether in competition with dingo or not, has been extinct for a sufficiently long period of time in Australia for its religious, legendary and food significance to have disappeared from the aboriginal tribes. The aboriginal may have had considerable impact on the number of *Sarcophilus* in Australia but it difficult to assess whether this would be in a negative or positive manner. The devil in modern Tasmania makes wide use of human settlement and garbage for food and the presence of aboriginal man may have offered a similar dietary supplement in Australia. On the other hand it may be that devils offered either a source of food to the aborigines or else suffered as a result of food competition with the aborigines.

Gill (1953) noted that *Sarcophilus* was one of the species that disappeared from Australia during the period of the occupation by black man and he went on to make the intriguing point, though this is not supported by fossil evidence which shows them to be contemporaneous about 3 000 years ago (Lowry and Lowry 1967), that the thylacine probably became extinct on continental Australia before the devil. This may well be comparable to the present Tasmanian situation where the thylacine, to say the least of it, is extremely rare although devils are still numerous.

There can be little doubt that white man has not expedited the extinction of this species from Australia in spite of Kershaw's (1912) record. Such a vociferous and flamboyant species as *Sarcophilus* would be expected to be handed down for many years in native song, dance and legend. There is no evidence of this and presumably therefore the species was not known to the natives in the near past.

With even greater certainty it can be said that the fox, introduced about 1868 (Rolls 1969) cannot have been a competitor with *Sarcophilus*.

The Tasmanian devil has experienced at least one major population cycle since the settlement of the island in 1804. Although early records are scanty, it would seem that devils were common in the 1820's and very common in some districts (Meredith 1850). Apparently they suffered a diminution in numbers as Gould and later writers found them only in the remote districts and this situation prevailed for many years, the species reaching its nadir about 1910 and remaining scarce until 1955 or thereabouts. This decline may have been due in part to a distemper-like disease that affected all the dasyures about that time (Burbury quoted by Guiler 1961). Much land clearance was taking place at about this time and the removal of cover, an important prerequisite for devils, would have assisted in confining the species to the mountains but at the same time additional food was supplied in the form of dead livestock and native species together with litter generally. The recent studies of devils have shown (Guiler 1978) that they make full use of these resources and have adapted well to the modern scene, living even in the outer suburbs of cities. It would be unlikely that agriculture would play a major part in the decline in numbers of devils.

Trapping of animals for fur used to be an important part of the Tasmanian rural winter scene and a feature was the setting of traps for devils to remove them from the trapline. Such activity could only have a local effect and would not control the total population.

The present population peak was not reached synchronously throughout the State and it may be that the Cape Portland population, although still high, may have passed its peak. However, the Midlands population currently is very high as is shown by the permit applications from Cressy, Auburn and Glenconnel. The relative abundance of devils cannot be assessed from the return per unit of effort in different places. The return per trap in 1974 at Granville (0.421) was obtained from a smaller number of animals than at Cape Portland (0.366) or Auburn (0.102). The yield of devils is controlled in part by the nutritional status of the population under study and also by the knowledge of the general patterns of devil movements and those of the local population by the workers concerned.

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(ms. received 12.10.1981)

A DESCRIPTIVE ECOLOGY OF THE VEGETATION IN THE LOWER GORDON RIVER BASIN, TASMANIA

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(with one text-figure and one table)

ABSTRACT

JARMAN, S.J., CROWDEN, R.K. and BROWN, M.J., 1982 (31 viii): A descriptive ecology of the vegetation in the lower Gordon River basin, Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 165-177. ISSN 0080-4703. Department of Botany, University of Tasmania and National Parks and Wildlife Service, Hobart, Tasmania.

The vegetation of the Lower Gordon River Basin consists of rainforest, sclerophyll forest, scrub and sedgeland-heath, each of which is composed of a number of plant communities forming an intricate mosaic.

Field studies conducted over three summer seasons suggest that differential fire regimes are the primary determinants of the composition, structure and distribution of the major vegetation types. Climatic, topographic and edaphic factors play a relatively minor role except through their interaction with the fire regime.

The observed patterns and processes in the major vegetation types can be interpreted readily in terms of vegetation succession and ecological drift, but the ubiquity of diffuse ecotones argues against the occurrence of stable fire cycles.

INTRODUCTION

The vegetation occurring on the pre-Carboniferous rocks of western and southwestern Tasmania has been a continuing source of fascination to botanists. Generalised descriptions of the vegetation have been given by Casson (1952), Jackson (1965) and Edwards (1978). More detailed regional descriptions are also available for the Norfolk Ranges (Macphail *et al.* 1975), the South West and Frenchmans Cap National Parks (Jackson 1974), the West Coast Range and environs (Kirkpatrick 1977) and for the Lower Gordon River area (Jarman and Crowden 1978).

Moscal (1979) provided descriptions of island and coastal vegetation types in southwestern Tasmania and Moscal (1980, 1981), Kirkpatrick (1980) and Kirkpatrick and Harwood (1980) discuss particular aspects of the alpine vegetation in the same region. However, detailed accounts of the ecology of the lowland vegetation in the heart of southwestern Tasmania are few. There are some studies of particular areas (Davis 1940, Macphail and Shepherd 1973, Brown, Shepherd and Jackson 1975) and a few papers which discuss the role of fire in relevant vegetation (Gellie 1980, Mount 1979, Bowman and Jackson 1981), but Jackson (1968) provided the only overview of environment-vegetation interactions. Jackson dealt mainly with the major vegetation formations and their dominant elements and his study was based largely on data from the Pieman River area.

The present study consists of an interpretation of the ecology of the vegetation described by Jarman and Crowden (1978) for the Lower Gordon River Basin. The vegetation in the study area is believed to be close to its natural state, with man-made disturbances minimal. The only exceptions are possible changes in some areas where the "natural" fire frequency may have altered in the recent past, and the introduction of a few alien plant species. However, such exotic plants are rare, being found only along the edges of the larger rivers or around established encampments.

THE STUDY AREA

The study area is based mainly on the lowland parts of the Lower Gordon River catchment (fig. 1), but also includes the upper reaches of the Hardwood River, which flows south into the Davey River catchment.

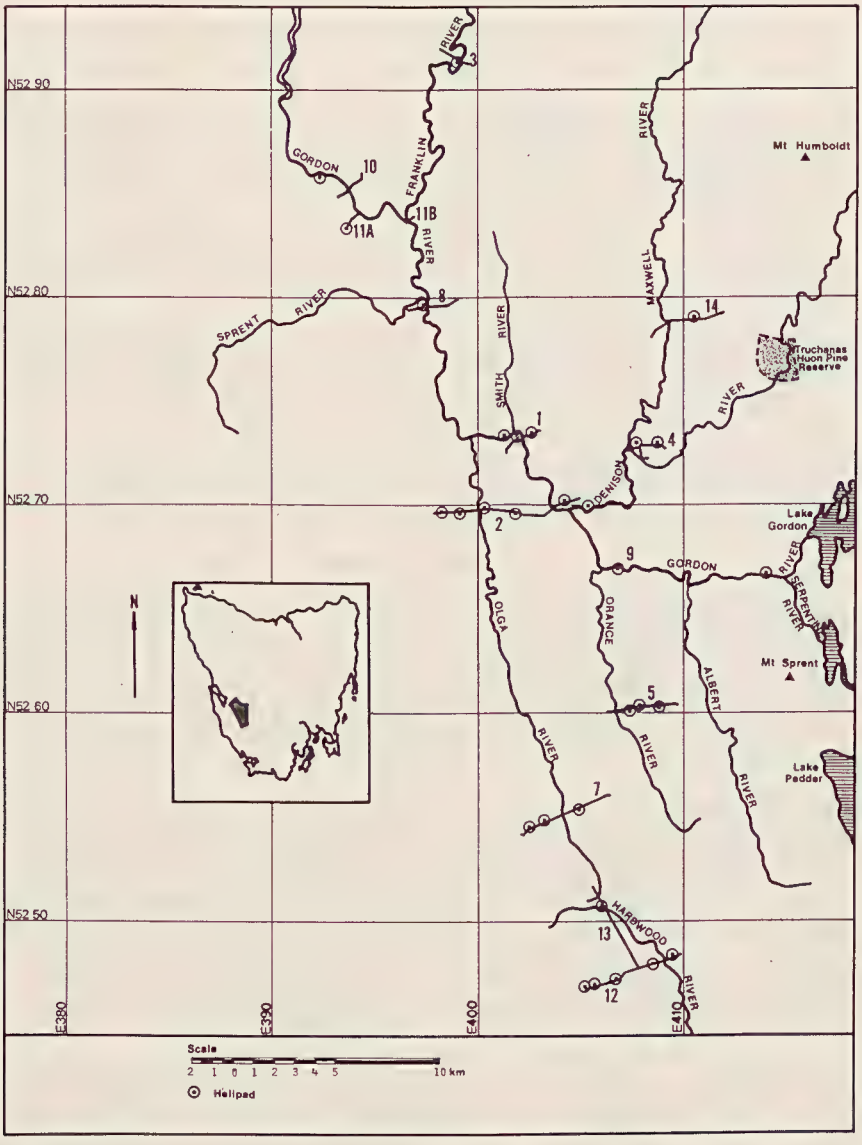

FIG. 1 - Location of survey transects within the study area (after Jarman and Crowden, 1978); there is no transect 6.

Climate

The highest rainfall in the State as well as the lowest rainfall variability in Australia is recorded from western Tasmania (Watson 1978). The rainfall is normally of low intensity and long duration, with a winter maximum which can be attributed to the greater strength and persistence of the prevailing winds during this season. Figures based on a six year period for Strathgordon at the eastern edge of the study area, show a median annual rainfall of 1620 mm in winter and 884 mm in summer (Watson, *loc. cit.*).

Air temperatures in the region (southwestern Tasmania) have a summer maximum and a winter minimum. Individual daily temperatures recorded on the Franklin River may vary from 37°C in the summer to -3°C in the winter (Watson, *loc. cit.*). The average annual hours of sunshine recorded at Strathgordon are 1528 hours. Fogs occur throughout the year and at Strathgordon, range from an average monthly frequency of 0.3 days in December to 7.3 days in July. Frosts occur throughout most of the year, but they are heaviest and most frequent from May to October (Watson, *loc. cit.*). In the higher areas, snow falls may occur at any time but they are infrequent in lowland areas and rarely persist.

Geology

The study area is underlain by approximately equal areas of Precambrian and Palaeozoic rocks which are covered by a thin layer of sands and gravel of fluvial and glacifluvial origin believed to have been deposited during the Quaternary Period (Roberts and Naqvi 1978). In Tasmania, the Precambrian rocks are divided into "Older" and "Younger" groups: both occur in the study area, although their boundaries have not been determined. The "Older" rocks are more deformed and altered than the "Younger" rocks and consist of metaquartzites, quartzite schists and graphitic schists. Rocks from the Palaeozoic Era can be assigned to the Ordovician, Silurian and Devonian Systems. The Ordovician rocks comprise the "Butler Island" Formation, consisting of sandstones and carbonates, and the Gordon Limestone Subgroup consisting of high and low grade limestones and calcareous and non-calcareous siltstones (Roberts and Naqvi, *loc. cit.*). The Silurian-Early Devonian rocks comprise quartzites, siltstones and argillites with minor calcareous horizons occurring as limestone, dolomite and calcareous siltstone (Roberts and Andric 1974, cited in Roberts and Naqvi, *loc. cit.*).

Soil

Soils are high in organic material, forming peats of varying depth and characteristics (Tarvydas 1978). The peat is usually separated from bedrock by a layer of sand, gravel or silt, or less frequently, by clays. There is little or no development of pedogenic horizons in these substrates, although an iron pan was present in a few soil pits. The organic soils are not related to their mineral substrates, although there may be some admixture, either within or at the base of the organic horizon (Tarvydas, *loc. cit.*). Mineral soils forming the surface horizon are rare.

The peats can be divided into muck peats and fibrous peats. Muck peats occur in low-lying water logged areas where the water table is usually shallow. Tarvydas (*loc. cit.*) comments that the vegetation is much reduced in size on these peats and no forests occur there. The fibrous peats can be further subdivided into soft reddish brown peats which occur throughout the area below forests (and some scrub) and a dark grey, almost black, fibrous peat which occurs most frequently in the better drained sedgeland-heaths of the Olga, Hardwood and Maxwell River valleys. At some sites, particularly in the button grass communities, the organic layer is partly or almost wholly comprised of a living root mat derived from monocotyledons and small shrub species.

METHODS

The study was undertaken as part of a wider scientific survey which was organised by the Hydro-Electric Commission of Tasmania to provide an environmental statement about possible power developments in the area.

Thirteen transects were chosen to include representative samples of the different vegetation, topographical or geological types in the area. The total distance traversed exceeded 45 km. Soil and rock characteristics were determined from ca. 230 soil pits (Tarvydas 1978) and vegetation sampling took place at 50 m intervals along the transects and/or at each soil pit. Only vascular plants were included. Estimates of the height classes and projected foliage cover (modified after Specht 1970) were made at each site. The work was carried out over three consecutive summer seasons (Nov-March) commencing in 1976.

THE VEGETATION

The vegetation can be divided broadly into rainforest (the closed-forest of Specht 1970), sclerophyllous forest, scrub and sedgeland-heath. Each of these categories contains a number of communities which differ in their structural and/or floristic detail (table 1). Descriptions of the individual communities have been given by Jarman and Crowden (1978) and detailed phytosociological analyses will be published elsewhere (manuscript in prep.). The term "sclerophyllous forest" is used here to encompass two forest types. The first of these is common in and may be considered typical of the region. The dominant species is usually but not necessarily a eucalypt, and the layer of greatest density is represented by medium and low trees. Small or fine-leafed species such as *Leptospermum glaucescens, L. nitidum, L. scoparium, Melaleuca squarrosa* or *Acacia mucronata* are dominant in this layer. *Phebalium squameum* is a frequent component, but other notophyllous species are rare or absent. Tall, medium or low shrubs occur only sporadically. Many of the tree species present normally grow as shrubs in eastern Tasmania.

The second forest type, "wet sclerophyll" or wet eucalypt forest (Jackson 1965, Ashton 1981) is rare in the study area. The dominant species are eucalypts and elsewhere in Tasmania the dense tall shrub layer is typically comprised of notophyllous species such as *Olearia argophylla, Bedfordia salicina, Prostanthera lasianthos, Zieria arborescens, Phebalium squameum* and *Pomaderris apetala*. However, *Olearia argophylla* and *Bedfordia salicina* were not recorded anywhere in the study area, and *Prostanthera lasianthos* was found only along the edges of rivers and creeks.

Sedgeland-heath is a composite vegetation type encompassing sedgelands, heathlands and vegetation in which shrubs and "sedges" are more or less co-dominant. The term sedge here includes species from both the Cyperaceae and the Restionaceae.

ECOLOGICAL RELATIONSHIPS

The climatic climax of the study area is cold temperate rainforest (Jackson 1968), but the vegetation forms a mosaic of rainforest, sclerophyllous forest, scrub and sedgeland-heath. Each of these vegetation types maintains a relatively uniform appearance but supports a vast range of internal floristic and structural variation (table 1). For example, at least eleven different sedgeland-heath communities can be identified in the button grass vegetation of the Olga and Hardwood valleys. In these, buttongrass (*Gymnoschoenus sphaerocephalus*) may be dominant and form a more or less monospecific community, it may occur in admixture with low heathy shrubs or it may be present as depauperate clumps in essentially *Leptocarpus tenax, Lepyrodia tasmanica* or *Lepidosperma filiforme* sedgelands. Species diversity may vary from less than five species to more than twenty-five, and total cover of vascular plants may vary from less than 30% to over 100%. Similar variation is also apparent in the scrub and forest communities.

TABLE 1

A SUMMARY OF THE MAJOR PLANT COMMUNITIES IN THE LOWER GORDON RIVER BASIN

The table includes the interpretation of the plant communities in terms of Specht's structural classification (1970). Part B1 is not regarded as a community but represents a general summary of eucalypt forests, irrespective of their understoreys. C closed, F forest, Hm hummock, Hth heath, L low, O open, Sc scrub, Sg sedgeland, Sh shrubland, T tall, W woodland.

A. RAINFOREST COMMUNITIES

1. *Nothofagus cunninghamii, N. cunninghamii-Atherosperma moschatum*
   TCF, TOF, CF, OF
2. *Nothofagus cunninghamii-Eucryphia lucida*
   TCF, TOF, CF, OF, W, LCF, LOF
3a. *Nothofagus cunninghamii-Eucryphia lucida-Anodopetalum biglandulosum*
   OF, W, LOF, LW
3b. *Nothofagus cunninghamii-Eucryphia lucida-Acradenia frankliniae*
   TOF, TW, CF, OF, W, LCF, LOF
4. *Agastachys odorata-Cenarrhenes nitida-Nothofagus cunninghamii*
   W, LOF, LW
5. *Dacrydium franklinii, D. franklinii-Nothofagus cunninghamii*
   CF, OF

B. SCLEROPHYLLOUS FOREST

1. *Eucalyptus nitida* and/or *E. ovata*
   TOW, TW, OF, W, LOF, LW
2. *Acacia mucronata-Phebalium squameum (-Eucalyptus nitida)*
   CF, LCF, (OF, W, LOF, LW)
3a. *Leptospermum glaucescens-Acacia mucronata (-Eucalyptus nitida)*
   CF, OF, LCF, LOF (OF, W, LOF, LW)
3b. *Leptospermum glaucescens-Banksia marginata (-Eucalyptus nitida)*
   LCF, LOF, LW (OF, W, LOF, LW)
4. *Banksia marginata-Melaleuca squarrosa-Eucalyptus ovata*
   OF
5a. *Leptospermum lanigerum-Melaleuca squarrosa-Gahnia grandis (-E. ovata)*
   W, LCF, LOF (OF, W)
5b. *L. lanigerum/M. squarrosa* over *Bauera rubioides-Calorophus elongatus*
   LCF, LOF, LW
5c. *L. lanigerum/M. squarrosa* over *Myriophyllum amphibium*
   LOF
5d. *L. lanigerum/M. squarrosa* over *Gleichenia dicarpa*
   LOF, LW
6. *Phyllocladus asplenifolius-Eucalyptus nitida/E. ovata*
   OF, W

C. SCRUB COMMUNITIES

1. *Bauera rubioides*
   CSc
2. *Leptospermum glaucescens-Banksia marginata*
   CSc, OSc, TSh
3. *Leptospermum nitidum-Melaleuca squamea (-Banksia marginata)*
   Csc, OSc, TSh
4. *Melaleuca squarrosa-Melaleuca squamea*
   CSc, OSc, TSh
5. *Melaleuca squarrosa-Leptospermum lanigerum*
   Csc, OSc, TSh

D. HEATHLAND/SEDGELAND COMMUNITIES

1. "Monospecific" *Gymnoschoenus sphaerocephalus*
   CHmSg
2. *Leptospermum nitidum-Sprengelia incarnata-Gymnoschoenus sphaerocephalus*
   CHth, OHth, HmSg
3. *Leptospermum glaucescens-Sprengelia incarnata*
   CHth, OHth, HmSg
4. *Sprengelia incarnata-Epacris lanuginosa*
   OHth
5. *Restio monocephalus-Lepidosperma filiforme-Sprengelia incarnata*
   OHth, Sg
6. *Leptospermum scoparium-Dillwynia glaberrima-Boronia citriodora*
   CHth
7. *Gymnoschoenus sphaerocephalus-Sprengelia incarnata-Gleichenia dicarpa*
   OHth, HmSg, Sg
8. *Leptocarpus tenax-Lepyrodia tasmanica-Helichrysum pumilum*
   Sg
9. *Leptospermum lanigerum-Melaleuca squarrosa-Hakea epiglottis*
   CHth, OHth, LSh
10. *Lepidosperma langitudinale*
   CSg, Sg, OSg
11. *Baumea juncea-Liparophyllum gunnii*
   Sg, OSg

Changes in the vegetation are rapid and there are no extensive areas of "pure" communities. Up to eight communities were encountered within 500 m on some transects. This complexity reflects the complicated interactions between the vegetation and the environment. The most pronounced single environmental influence appears to be fire, but fire is also influenced strongly by climate and topography. Similarly the effects of edaphic factors are most readily explained within a framework of fire-induced vegetation formations.

A separate discussion of the relationships between vegetation characteristics and each of four major environmental factors is given below. These interactions are discussed at two levels, viz. those which influence the distribution of major vegetation types (rainforest, sclerophyllous forest, scrub, sedgeland-heath) and those which influence the distribution of the plant communities within each of these vegetation types.

1. Climate and Vegetation

The study area is too small for macro-climatic effects to be marked. Rather the influence of climate on the vegetation is indirect, operating through the day to day variations (weather) on fire characteristics. During dry periods of very high temperatures, any fires which occur are likely to be of high intensity, and coupled with strong winds, will cause widespread severe damage. In less extreme conditions, the interaction between weather, topography and the vegetation will set up differential moisture gradients and these in turn will influence the direction and extent of fire damage. Furthermore, once an area has been burned, then weather and local micro-climate will strongly influence the success of regeneration of the original vegetation through their effects on germination and maintenance of suitable growing conditions for young seedlings.

2. Topography and Vegetation

The altitudinal range of the study transects (most below 300 m ASL) is small and has a negligible effect on the vegetation. The distribution of vegetation types is not related simply to aspect. The hills and valleys of the study area are aligned in a north-south direction. The east and west facing slopes support all of the major vegetation types, which can all be found also in flat areas on ridges and on valley floors. The predominant influence of topography on the vegetation appears to operate through its interaction with such other environmental factors as drainage, micro-climate and fire frequency. Particular sites, e.g. ridge tops, will dry out before others, e.g. gullies and south facing slopes, and will become susceptible to fire disturbance before the surrounding vegetation. Examples of this can be seen on the eastern hills along the Olga Valley (and also the lower Maxwell Valley) where caps of eucalypts occur on ridges and small hills whilst the surrounding vegetation is predominantly rainforest. Similarly, steepsided river valleys retain their moisture longer than wide flat valleys where the open terrain encourages evaporation and reduces the influence of river fogs. The effect of fires in the moister situations will be reduced compared to the drier areas and the moisture differences may be sufficient to completely discourage fire.

At the community level, an interaction between topography and vegetation is apparent in some cases but again, the effect is indirect, acting through the influence of topography on drainage conditions (see 3c below).

3. Edaphic Factors and Vegetation

(a) Geology

The different geological types in the area are capable of supporting all four major vegetation formations. Rainforest and sclerophyllous forests occur on Precambrian rocks on transects 4, 5 and 14 and on Devonian, Silurian and Ordovician on transects 1,

2, 7, 8, 12 and 13. They occur on limestone (transect 2), sandstone (transect 2, 11A), dolomite (transect 14) and quartzite (transect 5, 12) and where sandy loams, gravels or clay underlie the peat. Similar examples for scrub and sedgeland-heaths can be found throughout the area. Typically, the plants accumulate a humic peat of uniformly low pH which seems to buffer any effects of the underlying rock, even on alkaline limestone or dolomite substrates. In most soil pits examined, the peat is separated from bedrock by underlying gravels and sand. Root penetration beyond the peat layer is rare except where clays and loams occur immediately below, offering additional nutrients. Thus, the interaction between plants and bedrock is minimal, because the plants maintain a growing medium which is largely independent of the underlying geology.

Exceptions to this situation occur when the layer of peat has been removed, or its development has been impeded and mineral soils have developed. In the Olga and Hardwood River valleys there are small sandy pans having an alkaline pH (7.5-8.5) at the soil surface. These pans support a flora which is quite distinct from that of the surrounding sedgeland-heath and scrub communities where soil pH averages 4.0-4.5. In fact the communities are zoned across the margins of the pans according to the gradient in pH (Brown, Crowden and Jarman 1982).

(b) Soils

Except for the sandy pans, the soils of the study area have a uniformly high organic content. In forested areas (rainforest, sclerophyllous forest) and the older scrub communities (e.g. *Bauera* scrub), the soils are comprised of red brown fibrous peats; in well-drained sedgeland-heath communities dark fibrous peats or root-mats develop, whilst in poorly drained situations, the sedgeland-heaths grow on muck peats. Since the soil is composed mainly of material contributed by the vegetation, it is unlikely that soil independently governs the observed distribution of vegetation types.

The nature of the peats beneath any given community will be conditioned by the complement of species it supports. Thus soil properties such as nutrient status, aeration, water retention, amount and type of decomposition products (humic acids, toxins) and the rate of litter humification will vary from place to place. These properties will have a significant bearing on the potential of the site for colonisation by species from neighbouring sites. They may also differentially determine the ability of species to persist at a site.

(c) Drainage

The combination of topographic variation, hydraulic conductivity of the soil and variable depth to bedrock provides a wide range of drainage conditions throughout the area, from well-drained steep slopes to flat, waterlogged situations.

The distribution of the major vegetation types is not related closely with this range of drainage patterns. Rainforest, sclerophyllous forest, scrub and sedgeland-heaths all occur on sites where the drainage is poor. They are also to be found on well-drained sites. However, drainage is probably the most important environmental factor after fire to influence the distribution of the individual plant communities. In the button grass plains, a number of communities occur only at sites where drainage is poor (e.g. *Lepidosperma longitudinale* sedgelands, *Gymnoschoenus sphaerocephalus-Sprengelia incarnata-Gleichenia dicarpa* sedgeland-heath, *Melaleuca squarrosa-Leptospermum lanigerum* and *Epacris lanuginosa-Sprengelia incarnata* heaths). Other communities occur only at sites of good drainage (e.g. *Leptospermum scoparium-Dillwynia glaberrima-Boronia citriodora* and *Leptospermum glaucescens-Sprengelia incarnata* heaths). *Restio monocephalus-Lepidosperma filiforme* sedgelands also occur in well-drained situations but only where soils are very shallow, with scattered gravel or stones on the surface. Some sclerophyllous forest communities occur only in flat, poorly-drained situations (*Leptospermum lanigerum* and *Melaleuca squarrosa* forests) whilst others are confined to ridges, steep slopes or raised areas where drainage is better (e.g. *Leptospermum glaucescens-Acacia mucronata-Eucalyptus nitida, Phebalium squameum-Acacia mucronata, Eucalyptus* forests). The distribution of rainforest communities is less clear, but

Nothofagus cunninghamii-Atherosperma moschatum and *Nothofagus cunninghamii-Eucryphia lucida* forests were not found in poorly-drained areas. Other rainforest communities were found over a range of drainage conditions.

(d) pH

The soil pH (3.5-4.5) is relatively constant (Tarvydas 1978), except for the sandy alkaline pans, where values may reach pH 8.5. In the forest communities, there is no evidence to support Jackson's (1965, 1968) suggestion that the distributions of *Eucryphia*, *Phyllocladus*, and *Anodopetalum* directly reflect altered pH levels.

(e) Nutrient status

Maclean (1978) sampled nutrients in soils beneath sedgeland-heath scrub communities at six sites in the Orange and Olga River valleys. Total and available N and P, total and exchangeable cations (K, Na, Mg, Ca and Fe), and exchangeable bases were measured and have been cited in Bowman and Jackson (1981). The results showed that soils beneath *Gymnoschoenus sphaerocephalus* dominated vegetation were impoverished compared with vegetation in which heath and scrub plants are dominant.

Maclean (1978) also compared the percentage withdrawal of elements from dying leaves of *Gymnoschoenus* and *Lepidosperma filiforme* with the results given for the leaves of *Eucalyptus nitida*, *Nothofagus cunninghamii* and *Atherosperma moschatum* by Harwood (1972, cited in Maclean 1978). Both *Gymnoschoenus* and *Lepidosperma* were found to be very efficient in withdrawing P and K from the leaves, and although less efficient in withdrawing Mg, their ability greatly exceeded that shown by *Nothofagus* and *Atherosperma*. However, with respect to Ca, the two rainforest species were more efficient than the two sedges. *Eucalyptus nitida* showed values intermediate between the sedge and rainforest species for all elements except P in which it stands between *Nothofagus* and *Atherosperma*. Overall, the results suggest that litter (and therefore the soil) accumulating in rainforest communities will be richer than that found in sedgeland-heath communities, at least with respect to phosphorus, potassium and magnesium. Thus there may be a gradient in nutrient levels in soils from button grass communities through eucalypt communities to rainforest. Such a gradient is obviously closely dependent on the vegetation itself.

Any nutrients which are returned to the soil through decomposing litter may be removed or transferred by leaching into gullies and water-courses. Thus some differences in nutrient levels would be expected between peats occurring on ridges and those present in gullies and along river banks. However, nutrient differences between these sites are confounded with a host of other environmental variables, any of which may also contribute to differences in the vegetation.

4. Vegetation and Fire

The widespread occurrence of charcoal on living and dead plants, and the existence of distinct vegetation boundaries which can be correlated with known fires leaves no doubt that burning has an important influence on vegetation patterns in the area. Gilbert (1978) stated that "in the wild, suitable conditions for the establishment of a new generation of eucalypts are provided by fire, and with few exceptions, by fire alone". This being the case, then the widespread (if sometimes sporadic) occurrences of eucalypts, along with the presence of charcoal fragments well below the soil surface (Tarvydas 1978) suggests that fire has existed as a major influence for a long time, and is probably the most important single factor deflecting the climatic climax.

For the most part, the observed distribution of the major vegetation types in the study area can be interpreted by the model proposed by Jackson (1968) relating vegetation changes to varying fire frequency. Jackson proposed that on poor soils, a high fire frequency (12-25 years) will result in the establishment of hummock sedgeland communities. As the average interval between fires increases, these will give way to scrub moors with an increasing number of woody species. These in turn, will be replaced by wet scrub comprising tall *Leptospermum* and *Melaleuca* species mixed with open eucalypt stands. Rainforest shrub species are often present and these may become stable dominants in 50-70 years without fires. Where the average interval between fires is approximately 150-200 years, "mixed forest" (Gilbert 1959) will become established and this will convert to

pure rainforest providing the interval between fires exceeds the life span of the eucalypts (c. 350 years).

In the study area, eucalypts may be completely absent throughout the succession and "mixed forest" as defined by Gilbert will not develop. However, the general principle remains unaltered - the "mixed forest" being replaced by a community composed of other sclerophyllous species, e.g. *Leptospermum*, *Melaleuca*, *Acacia* species, etc., in admixture with the rainforest species.

Jackson's model includes two time relationships between vegetation patterns and fire frequency. Firstly it gives the probable fire regimes required to maintain the general physiognomy of individual vegetation types and secondly, an approximate estimate of the time required to move from one vegetation type to the next in the absence of fire. No attempt was made to verify these times but ring counts from miscellaneous stems sampled from a few communities did not conflict with the time scales suggested by Jackson.

In the absence of fire (i.e. assuming an uninterrupted "forward" progression) the time scale for each stage in the progression from heathland to rainforest will depend on many factors including species composition, drainage, nutrient status of the soil, etc. Further, the transition between vegetation types is controlled by at least two different strategies, i.e. internal competition and external invasion, and progress at any stage will depend on which strategy is exerting the greater influence. The fastest progress can be expected when internal competition is involved, in which floristic composition at all stages in the succession is included in that of the initial community, and development proceeds by elimination of less competitive species (c.f. Noble and Slatyer 1981). Under favourable growing conditions the transition will take place relatively rapidly since it depends mainly on the growth rate of individual species. In contrast, external invasion will proceed relatively slowly since it depends on several factors such as proximity to the nearest seed source and appropriate conditions for seed germination and seedling establishment. If the seeds require high light levels for germination or for establishment, it may be necessary to await some clearing of the present plant cover before the invader can become established. Active invasion is then limited to times of disturbance, e.g. from floods, fires or landslips. Further, with those species whose seed are not dispersed by wind or animals, it may involve a slow stepwise movement from some distant community.

In the study area, large tracts of sedgeland-heath are present which contain potential scrub and sclerophyllous forest plants as well as true heathland species. Thus, the sporadic occurrence of *Banksia marginata*, *Agastachys adorata*, *Cenarrhenes nitida*, *Acacia mucronata*, etc., as well as the more abundant occurrence of *Leptospermum* and *Melaleuca* species in this vegetation will ensure a progression from heathy sedgelands through scrub to sclerophyllous forest. The dominating strategy appears to be that of internal competition. As the canopy above the heath communities begins to close, many of the smaller species are eliminated. The most probable contributing factors are reduced light and/or nutrient availability. *Gymnoschoenus sphaerocephalus* is one of the more prominent species which may be eliminated in this manner, and at several sites, dying or dead hummocks were observed below closed canopies of *Leptospermum* and *Melaleuca* scrub.

However, there are some communities in which the progression from sedgeland to forest is unlikely to conform to the time scale suggested by Jackson's model. For example, in "pure" button grass communities, shrubs are absent and species diversity is very low, being restricted mainly to monocotyledons and herbaceous dicotyledons. Shrub species such as *Melaleuca squamea* and *Leptospermum nitidum* appear to be gradually establishing in the hummock sedgeland by slow invasion from nearby scrub communities. However, establishment apears to be very slow and successful invasion is not inevitable, even after initial seedling growth. There is some oscillation apparent near ecotones where mixed age living and dead plants occur side by side. Thus, the eventual change to forest is likely to be exceedingly slow. Communities with few potential shrub and forest species include *Leptocarpus tenax-Lepyrodia tasmanica* and *Restio monocephalus-Sprengelia incarnata* sedgeland-heaths. If these communities achieve the appropriate complement of woody species by invasion, their progression to sclerophyllous forest should then conform to Jackson's model. Eucalypts are absent from most sedgeland-heaths in the Olga and Hardwood valleys.

Jackson (1968) suggested that at very high fire frequencies the survival of even mallee types of eucalypts is limited. The occurrence of eucalypts in isolated pockets in the valleys and on the surrounding hills suggests that they may have been more widespread in the past but have been eliminated from many sites by at least two fires in very close succession. In these sedgeland-heath communities, the presence of eucalypts in the eventual sclerophyllous forest is unlikely. Eucalypts can only occur by invasion from adjacent communities and because of their limited seed dispersal, short seedlife and particular germination requirements, their establishment is probably limited to boundary encroachment after some disturbance has opened the canopy.

The conversion of sclerophyllous forest to rainforest depends mostly on external invasion, although a few species, e.g. *Cenarrhenes nitida* and *Agastachys odorata* may have been maintained from the sedgeland-heaths. Evidence of transition to rainforest can be found at both well-drained and poorly-drained sites supporting sclerophyllous forests. These forests usually contain small scattered rainforest plants below the main canopy, as well as larger plants at the boundaries when rainforest communities are adjacent. The dominant rainforest species, *Nothofagus cunninghamii* seems well adapted for this invasion, with its low light requirements for seed germination and seedling establishment. Other species, e.g. *Eucryphia* spp., *Anodopetalum biglandulosum* and *Anopterus glandulosus* have seeds which possess wings, suggesting an adaptation to wind dispersal, whilst species such as *Cenarrhenes nitida* and *Cyathodes juniperina* produce fruits dispersed by bird vectors. (The germination requirements of none of these latter species are known.) The time involved in the transition to rainforest will vary greatly between sites depending in particular on the nearest rainforest communities and it is difficult to imagine the transition occurring at some sites in the time proposed by Jackson, e.g. in isolated pockets of sclerophyllous forest surrounded by sedgeland-heath.

Because of their inability to regenerate under closed canopies, the sclerophyllous forest species eventually will be eliminated from most rainforest communities. In the case of eucalypts, Jackson (1968) and Gilbert (1978) have suggested a life span of from 350 to 400 years. If fires occur at a longer interval than this at any one site, then eucalypts will be lost from the community. Once they disappear they will not re-establish after fire, except along the boundaries between rainforest and eucalypt communities. In rainforest communities where the canopy is not closed, some sclerophyllous species apparently can regenerate in the absence of fire. On several transects, small seedlings of *Leptospermum scoparium* and *Acacia mucronata* were observed on the track. Since the transects were narrow and the canopy disturbance minimal, it seems likely that under natural conditions, chance disturbances of the canopy, e.g. from falling trees, may be sufficient to allow some perpetuation of occasional sclerophyllous plants in the absence of fire. Presumably, if the canopy disturbance was sufficiently great, then eucalypts may also re-establish in this way.

An alternative model relating fire frequency to vegetation patterns in Tasmania has been proposed by Mount (1979). His model is based on the existence of "stable fire cycles" which result in specific fire regimes for each vegetation type. He argued that all vegetation types will burn providing they have exceeded their low fuel period, and given natural conditions, will regenerate the type of vegetation present before the fire. Mount's model downgrades the "chance" behaviour of fires and suggests a fixity of boundaries between different vegetation types. Further, on the basis of field observations, he states that there is "little evidence of change from one vegetation to another in the absence of fire".

Mount and Jackson's models reach agreement in postulating the existence of fire cycles which are characteristic of particular vegetation types. However, the models disagree on the "stability" of the fire cycles including the role of "chance" in determining the path taken by fires and the subsequent fluctuation in vegetation boundaries over time. They also disagree about succession (or drift) from one vegetation type to another in the absence of fire.

We can find little evidence to support Mount's idea of fixed boundaries within the vegetation. Mount (1979) stated that "the best evidence of the proposed model comes from the distribution of rainforest and sedgeland in western Tasmania. These two types are at opposite ends of the fire frequency scale, yet exist side by side over more than a million hectares (see Davies, 1965)". The only evidence we are able to find in Davies (1965) to support Mount's statement is the vegetation map which is produced at a scale of 1:1 800 000. We did not, anywhere in the study area, observe button grass sedgeland side by side with rainforest. A buffer zone of scrub and/or sclerophyllous forest was always present between the two and even the boundaries between the buffer zone and the sedgeland and the buffer zone and the rainforest were usually diffuse with inter-grading height and density of plants and intermixing of species. We also observed examples of "new" boundaries at several sites. For example, in the button grass sedgelands of the Olga River valley the 1969 fires have burnt some areas of sedgeland and not others. A check of species composition at adjacent burnt and unburnt sites suggested that a single community was present before the fire and only part of it was subsequently burnt.

Mount also suggested that "there is no valid case for re-arranging observations made in different places into a temporal sequence". Taken at its face value, Mount's statement may be correct. However, in the study area, the species composition, height and density of various vegetation types form continuous gradients, albeit gradients which are interrupted spatially throughout the area. Given the growth potential and ecological amplitude of the species present it is very difficult not to interpret the vegetation at one site as being an older version of vegetation at another site. Further, there is ample evidence to support succession and invasion throughout the area, e.g. young *Nothofagus cunninghamii* seedlings and saplings in sclerophyllous forest; dying or dead button grass (and spindly depauperate specimens of other sedgeland-heath species such as *Mitrasacme montana, Bauera rubioides* and *Empodisma minor*) in tall dense scrub adjacent to sedgeland areas; dead or dying *Gahnia grandis* in rainforest and sclerophyllous forest where the upper canopy is dense.

Although the obvious influence of fire is operating at the level of major vegetation types, it is probable that the distribution of some individual plant communities is also related to the variable "behaviour" of fires. In vegetation whose general physiognomy is maintained by an "average" fire frequency, the exact time interval between fires, their intensity, the time of year at which they occur and the actual sites burnt will vary between successive fires. The availability of seed and its longevity will vary between species as well as the suitability of conditions for seed germination. These factors in turn will influence the ratio between species which propagate mainly by seed and those which rely mainly on vegetative reproduction (Purdie 1977 a, b). They will also affect the ratio between species whose seed is short-lived and those whose seed remains viable for long periods (e.g. *Acacia melanoxylon*). Thus the variability of fire characteristics (including their unpredictability) will contribute to floristic diversity by providing environmental variations favouring different species at sites which appear physically similar.

CONCLUSION

The vegetation of the study area is an intricate mosaic of plant communities characterised by rapid changes across short distances. The plant communities can be allocated to one of four broader vegetation types, viz. rainforest, sclerophyllous forest, scrub and sedgeland-heath, which form a large-scale mosaic.

The distribution of the major vegetation types can be interpreted largely in terms of fire history. Sedgeland-heaths have apparently been maintained by a relatively high fire frequency, and as the frequency decreases, the vegetation changes through scrub to sclerophyllous forest and finally to rainforest. Rainforest is the climatic climax of the region, and unlike the other vegetation types, it is able to maintain itself in the absence of fires.

The area is too small for macroclimate effects to account for vegetation differences. Water is abundant, allowing many species to extend across boundaries within which they might otherwise be restricted, and all of the major vegetation types occur in a wide range of edaphic and topographic situations. Aspect differences are comparatively minor, but influence the vegetation secondarily through their influence on fire behaviour. Furthermore, the hills and valleys are aligned north-south so that cooler south-facing slopes and exposed north-facing slopes are uncommon. The strong correlations between vegetation and geology which are observed elsewhere in the State, are negligible in the study area, presumably because the vegetation is effectively isolated from the parent material by accumulated peat and underlying gravels.

Some individual plant communities are restricted to sites of good or bad drainage; others are restricted to river banks or to flat broad valleys. However, the distributions of many communities are not obviously related to readily discernible features of the environment. More detailed statistical analyses are being undertaken to determine whether there are probabilistic associations between the vegetation and such environmental features. Nonetheless, differential fire regimes appear to be the over-riding ecological determinants of vegetation distribution and succession in the area.

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A NOTE ON THE REPORTED OCCURRENCE OF STEEPLY-DIPPING TERTIARY BEDS ON OSMIRIDIUM BEACH, SOUTHERN TASMANIA

by R.F. Berry and S. Harley
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(with one text-figure)

ABSTRACT

BERRY, R.F. and HARLEY, S., 1982 (31 viii): A note on the reported occurrence of steeply-dipping Tertiary beds on Osmiridium Beach, southern Tasmania. *Pap. Proc. R. Soc. Tasm.*, 116: 179-180. ISSN 0080-4703. Department of Geology, University of Tasmania.

The steeply dipping beds at Osmiridium Beach, southern Tasmania, earlier identified as Tertiary are structurally and stratigraphically continuous with the ?Cambrian Pt Vivian Formation. The carbonaceous layers, used to support a Tertiary age, cut across the bedding and postdate some faults in the formation.

Twelvetrees (1915) reported a sequence of variably-dipping Tertiary strata from the western end of Osmiridium Beach. The steeply-dipping beds in this sequence were identified as Tertiary because of the carbonaceous zones which continue into them from overlying poorly-consolidated material including seams of brown coal. A sample of the carbonaceous material contained several angiosperm pollens which indicate a Late Cretaceous to Recent age (D. Taylor, pers. comm.).

The vertically-dipping beds of conglomerate and siltstone are lithologically indistinguishable from, and structurally continuous with those of the ?Cambrian Pt Vivian Formation (Berry and Harley, in prep.). Since the Pt Vivian Formation was folded during the Devonian orogeny a disconformity is unlikely at its boundary with the steeply-dipping beds claimed by Twelvetrees to be Tertiary. Also, the structural fabric of the siltstones does not change across this boundary. In addition, a set of shallowly-dipping quartz veins are continuous across the boundary proposed by Twelvetrees and a few quartz pebbles are offset along these surfaces indicating that the matrix, now poorly cemented due to weathering, was originally capable of transmitting substantial stresses to the pebbles.

Carbonaceous zones within the steeply-dipping beds were considered by Twelvetrees to continue into the overlying sediments. However the intensity of weathering of the steeply-dipping layers increases within 5 m of the angular unconformity with overlying poorly consolidated gravel. The vertical carbonaceous layers generally start at this boundary (fig. 1), crosscut the layering, and in one case form a distinct zone in a fault within the conglomerates. Some of the carbonaceous layers contain recognizable roots which are continuous along the zone for more than a metre. We interpret these carbonaceous zones as cracks filled with organic matter and clay during weathering and erosion before the overlying quartz pebble conglomerate was deposited.

At the eastern end of the outcrop there is a very weathered brown rock with randomly oriented root-like pieces of carbonaceous material. This is probably a fossil soil which survived as a pocket projecting downward into the ?Cambrian rocks from the angularly unconformable base of the poorly consolidated younger gravel.

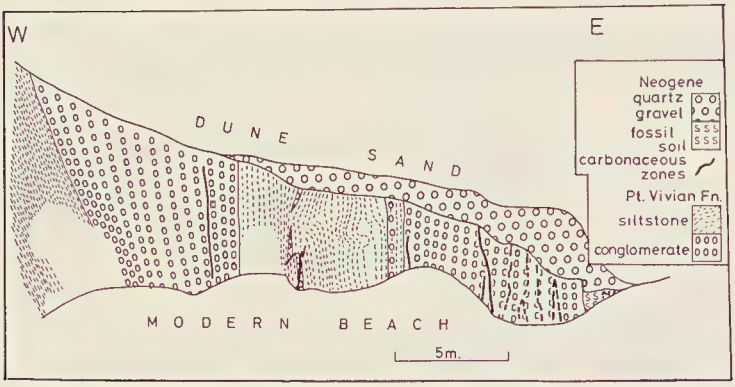

FIG. 1.- Sketch section of the rocks outcropping at the western end of Osmiridium Beach.

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OBSERVATIONS ON SOME TASMANIAN FISHES: PART XXVIII

by E.O.G. Scott
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(with six tables, nine text-figures and four plates)

ABSTRACT

SCOTT, E.O.G., 1982 (31 viii): Observations on some Tasmanian fishes: Part XXVIII. *Pap. Proc. R. Soc. Tasm.*, 116: 181-217. ISSN 0080-4703. Queen Victoria Museum and Art Gallery, Launceston Tasmania.

OPHICHTHYIDAE. *Ophisurus serpens* Linné, 1758: large scale stranding on Flinders Island; specimens described, compared with earlier material. NOMEIDAE. *Cubiceps caeruleus* Regan, 1914: first Tasmanian record; general account; ventral rays. REGALECIDAE. *Regalecus pacificus* Haast, 1878: general account, with photographs, of two recent local strandings; color pattern. CARANGIDAE. *Trachurus novaezelandiae* Richardson, 1843: additional records; comparison with first Tasmanian specimen, reported as *T. mccullochi* Nichols, 1920. SCOMBRIDAE. *Gasterochisma melampus* Richardson, 1845: specimen from western Tasmania (Earthwatch); comparison with earlier material; height of dorsal and anal finlets functions of dorsal and ventral body profiles. BOVICHTHYIDAE. *Pseudaphritis bursinus* (Cuvier, 1830): considered senior synonym of *P. urvillii*; detailed study with a critical review of published accounts of species; differential growth; length of ventral rays a function of height of body.

INTRODUCTION

This paper follows the general plan of others in the series. Linear measurements are given throughout in millimetres, unless otherwise specified, the name of the unit commonly being omitted. The symbols *Ls*, *Lt*, *TLs*, *TLt* denote standard length, total length, thousandths (permillages) of standard length, thousandths of total length, respectively. Registration numbers denoted by Q.V.M. are those of the Queen Victoria Museum and Art Gallery, Launceston. Certain other conventions are noted in earlier contributions.

Records of certain quantitative data (general morphometrics, including equations) not incorporated in the text are deposited with the Royal Society of Tasmania, Hobart, with a duplicate copy in the Queen Victoria Museum and Art Gallery, Launceston, Tasmania. The omission of such data from the published text is indicated at the relevant point by the notation (Appendix [number]).

SYSTEMATIC ZOOLOGY

Family OPHICHTHYIDAE

The snake eels or serpent eels, Ophichthyidae (frequently rendered Ophichthidae; in early texts, e.g. Günther (1880), subsumed in the wide Muraenidae) are distinguished at sight from the other groups of common large anguilliform fishes found in our waters — the typical eels Anguillidae, morays Muraenidae, congers Congridae (in most Australian texts Leptocephalidae), worm eels Xenocongridae (in most Australian texts Echelidae) — in having the dorsal and anal fins (where present, as is modal) ending in front of the tail tip, which projects as a stiff usually blunt naked process. They differ further from Muraenidae and Xenocongridae in being provided (in the great majority of cases) with pectoral fins, from the Anguillidae in lacking scales, and from the Congridae in having caniniform teeth. Of the eleven members of the family recorded from Australia (Munro 1957a), two only are known to occur outside Queensland, Northern Territory and Western

Australia, one, *Ophisurus serpens* (Linné, 1758) being found in Tasmania, New South Wales and Western Australia.

Genus *OPHISURUS* Lacépède, 1880

Ophisurus Lacépède, 1880, p. 195. Type-species, *Muraena serpens* Linne.
Ophisurus: McCulloch, 1929, p.68 (generic synonymy).

Ophisurus serpens (Linné 1758)

Muraena serpens Linné, 1758, p.244 (ed. 12, 1776, p.425: based on Artedi, gen.24, syn.41). Type locality: southern European seas.
Ophisurus serpens?: Ogilby, 1897a, p.85.
Ophisurus serpens: Macleay, 1882b, p.273: Ogilby, 1879b, p.159, footnote: McCulloch, 1921, p.35, pl.23, fig. 85a, and 1929, 5(1), p.68: Lord, 1923, p.64, and 1927, p.13: Lord & Scott, 1924, pp.8,37: Munro, 1957a, p.47, fig.330: Scott, 1963, p.15, fig.3, and 1980, p.105.
?Ophisurus serpens: Schlegel, 1850, p.264, pl.115, 1.
?Leptorhyncus capensis Smith, 1840, pl.6. Type locality: Table Bay, South Africa.
?Ophisurus macrorhynchos Bleeker, 1853, pp.9,28. Type locality: Kaminoseki, Japan.
?Ophisurus novaezelandiae Hector, 1870, p.34, pl.3. Type locality: Poverty Bay, New Zealand.
Leptognathus novaezelandiae: Whitley, 1964, p.36.

Occurrence in Tasmania

The early history in this State of this species has been reviewed in Part XI (1963). Lord & Scott (1924: 37) stated that they knew of no local reports other than the original one by Ogilby (1897a,b). A confirmatory record, based on a specimen, *Lt* 1144, found in a lagoon near the mouth of the George River, east coast, was given in Part XI (1963), and some observations on an example, *Lt* 601, hooked near the mouth of the same river, were presented in Part XXVI (1980).

Specific status

As pointed out earlier, the question as to whether the Tasmanian eel is conspecific with the European *O. serpens* or merely closely allied to it would appear to remain in doubt pending a direct comparison of specimens from the two hemispheres. Few precise observations on Australian material have hitherto been available; accordingly a general account of the first specimen received by the Museum was given, together with a figure illustrating the dentition. On receipt of additional examples the opportunity is here taken to record further morphometric and other specifications.

Large scale stranding

In October 1981 the Queen Victoria Museum, Launceston received from Mr K.W. Grace two examples of this species secured in unusual circumstances at Cameron Inlet on the east coast of Flinders Island, Bass Strait, a little south of the 40th parallel. Police Sergeant H.U. Schindler, Whitemark, who has been good enough to supply some information on the occurrence here noted, informs us that this body of water, about 3 km in length from its northern tip, adjoining the sea, to its more inland southern tip, and with a maximum width of 2-3 km, though designated an inlet is essentially a coastal lagoon with a facultative access to the sea. Though at one time opened regularly to the sea by the Rivers and Water Supply Commission, using a bulldozer to make a channel through the sand, it has remained landlocked for the past seven or eight years. Recently a spontaneous break-through occurred, and the lagoon, reduced in area by about half, became tidal. The depth of the area still under water was reduced to about two-thirds of a metre. In those parts where the water persisted — with an extensive growth of weeds and containing much evil-smelling decayed organic material brought in by numerous drains (the area being an abandoned Soldier Settlement) — the eels remained in general in a lively condition, hiding under weeds and when disturbed retreating to their burrows in the sand (the naked caudal end of the body of the ophichthyids is commonly held to act as a burrowing organ). However, some

hundreds were stranded high and dry, many showing evidence of damage resulting from exposure to the hot sun. Mr Schindler states the great majority were about three-quarters of a metre in length, with a few exceeding a metre. No stranded fish of any other species were observed. The two specimens forwarded to the Museum, *Lt* 904, 1 031 mm (Q.V.M. Reg. No. 1981/5/57) are here made the subject of some direct observations and of comparison with other Tasmanian examples from the east coast.

Dimensions

Specimens are recorded in order of increasing total length, (601, 904, 1 031, 1 144) all dimensions being thousandths of total length (in ophthichthyids effectively standard length). Length to origin of dorsal 104, 102, 102, 133, to termination 975, 989, 986, 987. Length to origin of anal 356, 350, 368, 407, to termination 983, 989, 988, 987. Length to vent (middle) 344, 345, 360, 363. Length to origin of pectoral 71.5, 68.6, 75.7, —, length of fin 14.5, 18.3, 17.7, 17.0. Head 68.2, 66.4, 73.7, 76.0 Snout 16.8, 16.6, 18.6, 20.0. Eye 6.7, 5.5, 6.7, 6.6. Interorbital 6.5, 6.0, 7.1, 8.0. Depth (in parentheses width) at front of eye 9.7(7.0), 9.3(7.9), 8.7(8.7), 12(9.6), at back of eye 11.3(8.3), 10.0(9.4), 13.6(11.6), 16(14); at gill slit 20.0(15.8), 16.9(16.6), 19.5(17.6), —(—), at dorsal origin —(—), 19.9(18.0), 21.3(20.4), —(—), at vent 15.1(16.3), 20.5(20.0), 22.3 (22.5), 17(17); maximum, head 21.6(15.8), 17.1(17.7), 20.3(18.0), —(—), body 16.6(16.6), 21.6(20.7), 22.3(22.8), —(—).

Proportions

Values for the five proportions given in the Handbook (Munro 1957a: 47) — these shown below in parentheses — for our four examples, in increasing order of total length are as follows. Mouth cleft in head, 2.1, 2.0, 2.1, 1.9(2.0): the large mouth cleft trenchantly distinguishes this from other Australian ophichthyids in which it is >3 in head. Eye in snout 2.5, 3.0, 2.8, 3.0(2.9). Head in trunk 3.8, 4.2, 3.9, 3.8(3.6-5.2). Head in tail 9.6, 9.9, 8.7, 8.4(7.1). Pectoral in head, 4.7, 3.6, 4.8, —(6). Other proportions of interest: eye in interorbital 1.2, 1.2, 1.1, 1.0: depth at front of eye in length of head 7.0, 7.1, 8.4, 6.3; at back of eye 6.0, 6.7, 5.4, 4.8; at gill slit 3.4, 3.9, 3.8, —; at vent 4.5, 3.2, 3.0, 4.5; maximum 4.4, 3.1, 3.30, —; length to dorsal origin in total length 9.62, 9.83, 9.83, 7.52: length to anal origin in total length 2.81, 2.95, 2.72, 2.46.

Dentition

The taxonomic importance of the dentition in ophichthyids has been demonstrated by Schultz (1953). This species presents a pattern of clustered premaxillary, uniserial maxillary, dentary and vomerine sets. Tolerably detailed accounts of the teeth have been given for the 1963 and 1980 individuals. The present specimens conform to the general pattern described earlier, but exhibit some individual variation. Dentary: anterior teeth in smaller fish 2 on right, 1 on left; in larger fish 2 on left, 1 on right level with first left, all large; median line of posterior hidden by fleshy lateral folds. Premaxillary: smaller, 1 small median, followed by 2 lateral largish, opposite one another; larger, 2 large on left, one large on right opposite hinder left, closely followed by 2 very slender, fine. Maxillary: usual long line of about 40 in each jaw. Vomerine: smaller, anterior spaced teeth 7, first not much smaller than second, thereafter increasing slightly in size (in both fish followed by usual hidden line of about a dozen small closely set).

Coloration

While exhibiting the characteristic bicolor pattern, fully specified for the earlier material, the present specimens show some individual variation, both relative to the east coast specimens and between themselves. Smaller example: dorsal and upper lateral surfaces greyish, faintly yellowish; lower half of side somewhat more yellowish (the two regions thus both lighter and less strongly contrasted than in the other individuals); ventral surface whitish behind vent, silvery in front of it. Larger example: back and side above lateral line rather dark brownish olivaceous; rest of side lighter, more sharply demarcated than in smaller example; in the anterior three-tenths of the trunk the lighter area, largely becoming whitish, sloping upward and forward to reach within about

one-fifth of height of fish from dorsal profile; ventral surface of trunk silvery, of tail white. Vertical fins, wholly withdrawn into grooves, appear as black or blackish lines, representing a narrow marginal band, the remainder of the fin, its maximum height subequal to eye, being translucent or pale greyish.

Lateral line

This consists of small simple pores; in the smaller example, in which they are more evident, 71 to vent + 135, ceasing about as far in advance of anal termination as latter is from tip. On the lateral surface its distance from the dorsal profile as about one-fourth that from the ventral profile, at some 4-5 pores behind this about three-tenths, at vent about one-third followed by a noticeable downturn, at halfway between vent and end a little less than half, at termination half. The extension from the flank on to the top of the head takes the form on each side of an outwardly convex arc of 5 evenly spaced pores, the two arcs joined anteriorly by a median pore at level of end of gape.

Cephalic pores

The dorsal, lateral and ventral surfaces of the head bear small simple pores regularly arranged: these have not previously been described in Tasmanian material. On dorsum three pairs on snout, first shortly in advance of the level of the tubular anterior nostril, second between anterior and posterior nostrils, third between latter and front of orbit; a pair near posterior one-third of interorbital; a widely spaced pair just behind eyes, followed by a median pore, its distance behind them subequal to the interval between them. On lateral surface of head, close to ventral border, a row of four, evenly spaced, the distance between the first and last subequal to that of the first from tip of jaw, the second and third below the eye; in an upward and forward line from the fourth two other pores, the lower behind eye by about half eye at level of middle of eye, the upper the postorbital pore already noted as occurring on top of head visible also in lateral view. On ventral surface in larger individual four pairs in advance of eye, interspace between first and second rather less than half interspaces between second and third and third and fourth; one pair about level with posterior border of orbit: in smaller individual nine pores arranged irregularly, perhaps interpretable as four pairs, the members set very obliquely instead of directly opposite, together with a hindmost azygous pore.

Family NOMEIDAE

The Handbook (Munro 1958b) listed as Australian nine members of the family Nomeidae (in some texts Psenidae), of which three are reported from Tasmania, (a) warehou or snotgall trevalla, *Seriolella brama* (Günther, 1860); (b) mackerel trevalla or snotgall trevalla, *Seriolella maculata* (Forster, 1794); (c) Patagonian silver trevalla, *Seriolella porosa* Guichenot, 1849. The earliest published Tasmanian catalogue (Johnston 1883) noted (in Carangidae) three species, *Neptonemus brama* Günther, 1860, *N. dobula* Günther, 1860 (which has Tasmania as type locality), *N. trevale* Castelnau, 1872: of these the first is species (a) above, the second, recognized in the Check-List (McCulloch 1929) as a valid species, is in the Handbook treated as a synonym of (c), while Castelnau's species is generally synonymized (as in the Check-List) with (a). In his second catalogue Johnston (1891) had the same species, with a note of interrogation following Castelnau's species. Lord (1923, 1927) and Lord & Scott (1924) listed (in Stromateidae) four species, namely, (a) as above, *Seriolella punctata* (Bloch & Schneider, 1801), recognized in the Check-List but treated in the Handbook as synonymic with (b), *S. dobula*, adding *Hyperoglyphe johnstonii* (Morton 1888) (type species of the genus *Eurymetopos* Morton, 1888; type locality Tasmania). The last-named does not appear in the Handbook, being represented there by *H. porosa* (Richardson, 1845) and being transferred from Nomeidae (in which both Morton's and Richardson's species are accommodated in the Check-List) to Centrolophidae; in his general review of the stromateoid fishes Haedrich (1967) also refers *Hyperoglyphe* Günther, 1859 to Centrolophidae, treating the two species noted above, together with the New Zealand *Seriolella amplus* Griffin 1928, as junior synonyms of *Perca antarctica* Carmichael, 1818 (type locality Tristan da Cunha).

At present the general taxonomic position in regard to a number of stromateoids would appear certainly to be in a state of indecision and perhaps of some confusion, stemming in part from the limits of the relation between *Schedophilus* Cocco, 1829 and *Seriolella* Guichenot, 1848, conclusions on which affect the scope of the families Nomeidae and Centrolophidae. In a paper on the occurrence of *Seriolella caerulea* Guichenot, 1848 in New Zealand waters McDowall (1980) referred it to Centrolophidae, at the same time observing "The scope of *Schedophilus* is in need of study and cannot be resolved here". In the present state of evident taxonomic uncertainty it is here deemed convenient (without espousing a definitive view on the matters in doubt) to follow the usage of the Handbook on the scope of the family Nomeidae.

Seriolella caerulae (type locality Juan Fernandez), reported from New Zealand by McDowall, who regarded it as a senior synonym of *Palinurichthys griseolineatus* Norman, 1937 (referred by Haedrich(1967) to *Schedophilus*) and the New Zealand *Seriolella tinro* Gavrilov, 1973, has been reported by Last & Harris (1981) from eight stations in Tasmanian waters at which trawls were made by the *Zeehaan* in January-March 1979. A further addition is here made to the Tasmanian list, that of *Cubiceps caeruleus* Regan, 1914. This species was not included either in the Handbook or the Check-List, the genus *Cubiceps* Lowe, 1843, being represented in the former by only *C. baxteri* McCulloch, 1923, and appearing in the latter only in synonymy of a species of *Psenes*. Haedrich (1967) concisely defined *Cubiceps* thus: "The combination of elongate body, long winglike pectoral fin, insertion of pelvics behind pectoral fin base, scales on top of head, cheeks, and opercles, and a patch of teeth on the tongue distinguishes *Cubiceps* from all other stromateoid genera".

Genus *CUBICEPS* Lowe, 1843

Cubiceps Lowe, 1843, p.82. Type-species, *Seriola grandis* Lowe 1843, by subsequent designation of Jordan & Evermann, 1896. [Lowe described his fish as a species in the genus *Seriola*, but noted (p.82) "Still it is not unlikely that a comparison of the two fishes [*S. gracilis* and *S. bipinnulata* (Quoy & Gaimard)] may warrant ... their separation from *Seriola* into a genus, which may be called *Cubiceps*"].
Cubiceps: Haedrich, 1967, p.178 (synonymy, noting five other generic or subgeneric names, *Altimostoma* A. Smith, 1849, *Navarchus* Filippi & Verany, 1859, *Trachelocirrhus* Doumet, 1863, *Mulichthys* Lloyd, 1909, *Mandelichthys* Nichols & Murphy, 1944, subgenus].

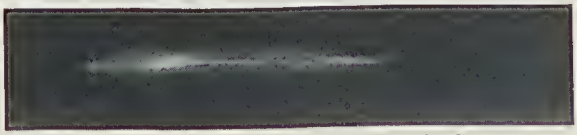

PLATE 1 - *Cubiceps caeruleus* Regan, 1914. Radiograph from ventral aspect of a specimen 258 mm in standard length from Bicheno, east coast, Tasmania (Q.V.M. Reg. No. 1980/5/55).

Cubiceps caeruleus Regan, 1914
(Pl.1)

Cubiceps caeruleus Regan, 1914a, p.15. Type locality: Three Kings Islands.
Cubiceps caeruleus Regan, 1914b, p.19.
Cubiceps caeruleus: Haedrich, 1967, p.81: McCulloch, 1923, p.15, pl.1, fig.3: Whitley, 1968, p.50: Hoese, 1976, p.436: Butler, 1979, p.231, fig.5.
?Cubiceps gracilis: Hutton, 1896, p.315. *Non Seriola gracilis* Lowe, 1843.
Cubiceps gracilis: Waite, 1904a, p.162, and 1904b, p.200, and 1910, p.375. *Non Seriola gracilis* Lowe, 1843.
Cubiceps capensis: Haedrich, 1967, p.81 (*part.*, all non-type material): Craddock & Mead, 1970, p.33: Haedrich, 1972, p.79: Karrer, 1975, p.75: Ahlstrom *et al.*, 1976, p.343: Pequeno, 1976, p.805. *Non Altimostoma capensis* Smith, 1849.

Distribution

Cubiceps caeruleus is an antiboreal species. Of two species with which the present form has been confused, one, *S. gracilis* appears to be restricted to the Mediterranean and a region around the type locality, Madeira, while the other, *C. capensis*, shows some overlap with our species. A distribution map in Butler (1979, fig.6) showed two entries off the coast of New South Wales and two in New Zealand. These with others form a chain of records between South America and somewhat southwest of the southern tip of Africa and between Australia and the west coast of South America: in the Peru Current it has been reported as far south as 19°S. There are no records between South Africa and Western Australia. Butler observed "The absence of records from the south Indian Ocean may reflect the paucity of sampling in this region". Specimens from Lord Howe Island have been noted by Waite (1904a,b), (as *S. gracilis*), McCulloch (1923) and Hoese (1976). The species is here for the first time reported from Tasmania.

Tasmanian material

In June 1980 Mr J. Billing observed several small fish in a rock pool at Bicheno, east coast, Tasmania; one was speared and submitted to the Queen Victoria Museum for identification (together with an inquiry as to whether it was edible!). The specimen (Q.V.M. Reg. No. 1980/5/55), *Ls* 258 *Lt* 304, has been determined as *Cubiceps caeruleus*, and is the subject of the subjoined observations. It had been cleaned, with loss of the branchial arches, and it has suffered further damage, notably in the first dorsal. Members of the genus *Cubiceps* are typically oceanic fishes — regularly found in the stomachs of porpoises and tunas and sometimes taken on tuna lines and in lift net fisheries (Butler 1979; specific references cited) — and though there are occasional records of stranded individuals, e.g. McCulloch (1923), the occurrence of *C. caeruleus* in the littoral situation here noted would appear to be quite exceptional.

Dimensions

Except where otherwise indicated the following dimensions are all recorded as thousandths of standard length: they include a dozen items for which Butler (1979, table 1) gave ranges and means for seven species of *Cubiceps*, his values being given here in parentheses. Total length 1178. Length to origin of first dorsal 382 (202-418, 378), to termination 492(?); to origin of second dorsal 610, to termination 899; to origin of anal 655 (580-679, 643), to termination 899. Length to pectoral, front of base 236, insertion of most advanced (uppermost) ray 271; length of fin, total 337, longest ray 329 ('pectoral fin length' 188-346, 308). Length to pelvic 357; length of fin, total 107, longest ray 97 ('pelvic fin length' 104-154, 120). Head 269 (216-365, 300). Orbit, longitudinal 62.4, vertical 69.8: as thousandths of head length 232, 259 ('orbit' 244-320, 276). Snout, from tip of upper jaw 62.0, from tip of lower jaw 64.0: as thousandths of head length 230, 237 ('snout' 243-286, 270). Interorbital 77.5: as thousandths of head length 288 (262-320, 290). Length of upper jaw 77.5: as thousandths of head length 288 (260-319, 295). Depth [width] at front of eye 139 [65.9], back of eye 190 [96.9], operculum 251 [116], dorsal origin 264 [116], vent 441 [109]; maximum 271 [120]; caudal peduncle, minimum 75.6, at origin of caudal ridges 77.5. Longest preserved dorsal spine, total 87.2, without distal filament 82.2; longest preserved ray 71.7; last 465. Longest preserved anal ray 58.1, last 32.9.

With the exception of snout relative to head (and barely here) our values fall within the ranges found by Butler, who examined some two score specimens: he pointed out the pectoral is longer than the head in examples of *Ls* >100 mm. The marked differences between extreme values are very probably accounted for as being due, over and above individual variation and possible locality factors, to allometric growth, well known to be common in stromateoids (involving particularly the lengths of the head and the paired fins, the predorsal and preanal length and overall depth), the effect of which in some instances leads to notable differences in general form — e.g. as noted in Part XXIV (1978: 347) in *Schedophilus huttoni* (Waite 1910) with age the dorsal migrates caudad relative to the pectoral, the origin of the former being in advance of that of the latter in small individuals but later coming to be above it.

Meristic characters

A. II, 23. D. XI (?, fin damaged), 27. P. 23. V. I, 5. C. 12 + 12 + 9/8. Scales along lateral line *ca* 53. L.tr. 7½/13½. A radiograph in which definition is better than in reproduction (pl.1) would seem to indicate the appropriate vertebral count of 31 (13 + 18 Haedrich, 12 + 19 Butler).

General description of specimen

Dorsal profile a continuous curve from tip of upper jaw to insertion of uppermost caudal ray; height above base line from most advanced point on snout to middle of caudal peduncle at level of hypural joint reaches maximum at 0.4 of standard length, being here 3.3 minimum height; sum of anterior 5 deciles 1.27 sum of remainder. Sequence of descending magnitude of deciles: 4, 5, 6, 3, 7, 2, 8, 1, 9, 10. Ventral profile a continuous sweep, with more variation in curvature than dorsal profile; maximum depth below same axis equal at 0.3, 0.4 of length, here 4.4 minimum; sum of anterior 5 deciles 1.67 sum of remainder. Sequence of deciles 4, 5, 6, 3, 7, 2, 8, 1, 9, 10. Polynomial equations for body curvature (Appendix No. I). Caudal peduncle short, deep, stout, its depth 1.3 in its length, which is 2.7 in head.

Head moderate, 3.7 in *Ls*, bluntly rounded, chin slightly in advance of most advanced point on upper jaw. Scales extend on to dorsum to cease at level of nostril, being bounded here by a sharply demarcated proconvex arc; about 20 scales in median line from level of opercular border, last 3-4 smaller than rest; this region bounded laterally to just behind level of hind border of orbit by a line of about 25 pores; between pores and upper rim of orbit a narrow naked fleshy strip along the middle of which runs the white supraorbital ridge, this being narrowly bordered above and below by blackish; at middle of eye squamous dorsal region with 7 lines of scales; naked area continuing round behind eye, irregularly minutely mammillated and ridged, its greatest width half an eye diameter, extending forward to become continuous with naked side and front of wholly naked, but randomly poriferous, snout; behind this region, and probably below it, head, including opercle, scaled. Nostril a small subcircular opening with low rim, on horizontal level with upper one-fifth of eye; direct distance from eye twice that from upper lip; internarial half interorbital. Maxilla just failing to reach level of front of eye; somewhat expanded distally, its greatest width about one-fourth length of jaw. Premaxilla not protractile. Supramaxilla absent. Posterior three-fourths of upper jaw overlapped by gelatinous preorbital, its margin entire. Lower jaw stout, bluntly rounded, projecting a trifle beyond upper. Even with mouth widely open angle of gape well in advance of eye, about at level of nostril, or below middle of lower jaw with mouth closed. Eye moderate, its horizontal diameter 0.9 vertical, 4.6 in head; about two and a half times as far from ventral as from dorsal profile; wholly covered with a somewhat bluish grey adipose sheath, exhibiting no indication of an extension forward around the nostril such as that noted by Haedrich (1967: 79) in a detailed diagnosis of the genus *Cubiceps*. Interorbital slightly exceeding height of orbit, subequal to depth of caudal peduncle, strongly convex transversely less so longitudinally. Whole opercle flexible, more or less membraneous, borders of the bones naked, translucent.

Opercular border entire; a subtriangular process at level of middle of eye, basal width, about half pupil, thrice length, the slightly concave sides largely formed by two small spines, embedded save at short acute tip, a similar but almost straight spine between them, also projecting slightly at a distance subequal to base of this process the border bears a small translucent linguiform process, its distal border briefly bilobed, embedded in it an opaque black structure, barely more than a tapering streak less than 1 mm long, not exposed distally, which may represent an incipient or a vestigial spine: border between these two processes, shown strongly concave in the illustration accompanying the only account of an Australian example of this species, that of McCulloch (1923), is here decidedly convex. Preoperculum differing markedly from its representation in that figure, wholly lacking the backward sweep at the angle; reaching its greatest backward extension barely below level of orbit, being here slightly rounded; descending for about an eye diameter a little obliquely down and forward, almost straight overall, slightly concave in lower half; after forming a slight angle continuing, more or less linearly, at an

angle of about 135° for an eye diameter, this section irregularly and minutely denticulate; thereafter forward and upward gently convex to termination below front of eye.

Teeth in upper jaw in a single series, small subconical mostly somewhat recurved, spaced, decreasing in size backward; in lower jaw teeth similar but lateral teeth somewhat stouter. Teeth on vomer large circular flatly mounded ('knobby'), about two score, forming an elongate subelliptical patch, width, greatest behind middle, about one-third length, which exceeds half eye; whole patch light orange, conspicuous against dark grey or black of surrounding palate. A line of about eight small teeth on each palatine, apparently not reaching forward to front of vomerine patch. Tongue smooth, very broadly rounded in front; on its hind half an elliptical orange patch of teeth, of similar size to vomerine patch of teeth but more bluntly rounded at ends; teeth somewhat more closely set. On the glossohyals two pale orange patches, somewhat shorter, decidedly narrower, than patch on vomer, teeth smaller, separated anteriorly by about their own length, diverging posteriorly.

Dorsal fin originating at 0.38 *Ls*, well behind pectoral origin, slightly behind pelvic origin (contrast McCulloch's plate); fin damaged; apparently with 11 spines. Second dorsal originating at 0.60 *Ls*, somewhat in advance of anal origin, rays decreasing in length caudad. Anal ending directly under second dorsal, last two rays elongated. Pectoral with upper anterior end of base just in advance of tip of opercular process; fin narrow, winglike, extending to within an eye diameter of anal origin; first ray one-fourth, second half, length of third (longest), so closely adherent to one another as to make upper border a single rigid gently convex rib. Examination of the figure of this species in the review of the genus *Cubiceps* by Butler (1979, fig.5) would suggest that the pectoral is there turned upside down with the smooth leading edge directed ventrally; such a curious reversal obtains with the right pectoral of our specimen, the abnormal posture now being so thoroughly established that the fin cannot be restored to its usual position without risk of damage. Pelvics small, pointed, extending less than halfway to vent, anterior two-thirds or more fitting into a wide groove; for lengths of rays see below. When the specimen is viewed from the right side the upper caudal lobe is seen to be folded over the lower, obscuring some four-fifths of it: such overlapping is noted by Haedrich as not uncommon. All scales have been lost. From its origin a little above level of highest point on supraorbital ridge, where it is two-thirds eye diameter below dorsal profile, the lateral line rises, in the course of rather less than half a head length, to be only half eye diameter from profile, a relation it maintains to second dorsal origin, behind which distance from profile continuously decreases to be half as great at fin termination.

Portions of the subdermal canal system on the flanks (the visibility of which must vary with circumstances of preservation) that are here apparent are as follows: a shallow off-white groove, of maximum width 0.5 mm, extending almost linearly from upper angle of operculum to middle of caudal base, above and below this a narrower line, combined width of these about half pupil diameter; between levels of pelvic insertion and vent about a dozen forwardly convex whitish bands, extending to a maximum of halfway towards dorsal profile and of three-fourths of way towards ventral profile; between these arcs a complex system of finer reticulating light lines. An arc of pores fringing lower lip; others in a row just external to either edge of the isthmus, which extends virtually to tip of lower jaw. The specimen quite clearly exhibits the characteristic 'stromateoid look' regarded by Haedrich as constituting a valid, if somewhat trivial taxonomic criterion: "It is a fat-nosed, wide-eyed, stuffed-up look, smug and at the same time apprehensive".

Coloration

General color, in total absence of scales, light reddish brown, each scale pocket outlined in dark brown, most extensively at posterior border. Naked portion of head fawn, in parts dusky. Dorsal spines and rays very dark straw; anal rays somewhat greenish yellow with rusty maculation; pelvic yellow with extensive dark brown spotting; pectoral pale yellow tending to brownish in upper part; caudal medium brown, darker in outer rays.

Ventral rays

The lengths of all five rays are a function of their reverse serial numbers, $L = bN'^{(k)}$, where N' = number of ray, counting cephalad.

Log L = 0.2284 log N' + 1.8546; t 11.397*; estimated (measured) lengths, *Tls*, 72(70), 84(86), 92(93), 98(99), 103(101).

A relationship of this type has been reported in these contributions for a number of unrelated species, the modal set of rays involved, however, being {1-4}. In a recent paper (Scott 1982) a relationship of the form $L = bN^{(k)}$ has been examined for *Creedia haswelli* (Ramsay, 1881), in which there are only four rays, to investigate which ray is likely to have been lost in this species from the full complement in the Creediidae, recorded by Nelson (1978) as five.

Body profiles

Polynomials have been calculated for the dorsal and ventral profiles as specified by 10 equidistant measurements of height above and depth below an axis from most advanced point to middle of caudal peduncle at hypural joint (Appendix No.I).

Family REGALECIDAE
(Pls 2-4)

In its broad connotation, as accepted by Greenwood *et al.* (1966) in their provisional classification of living teleosts, that is, with the inclusion of a small group of lampridiform fishes placed by some Australasian authors, e.g. Whitley (1933, 1968), Munro (1957b) in a separate family Agrostichthidae, originally proposed by Phillipps (1924) to accommodate the New Zealand *Agrostichthys parkeri* Benham, 1904, the family Regalecidae is represented in Tasmania by two species, the southern oarfish, *Regalecus pacificus* Haast, 1878, and Benham's streamer fish, *Agrostichthys benhami* Scott, 1934.

KEY TO REGALECIDAE RECORDED FROM TASMANIA

Length <30 height; no teeth; upper profile of head concave; maxillary plate deeper than long; eye >3 (≐ 4-5) in head; P. >10 (12-14); elevated anterior section of dorsal with >6 (8-20) rays; lateral line descending to within >⅓ (≐ 1/3) of total depth from ventral profile; size large (to >5 m) ..... *Regalecus pacificus*

Length >30 (≐ 45) height; teeth in lower jaw (2) and on vomer (3); upper profile of head convex; maxillary plate longer than deep; eye <3 (≐ 1.7) in head; P. <10 (8); anterior elevated section of dorsal with <6 (3) rays; lateral line descending to <⅓ (≐ 1/6) of total depth from ventral profile; size small (1 m) ..... *Agrostichthys benhami*

Genus *REGALECUS* Ascanius, 1772

Regalecus Ascanius, 1772: 5. Type-species, *Ophidium glesne* Ascanius.

Regalecus pacificus Haast, 1878

Regalecus pacificus Haast, 1877, p.646. *Nomen nudum.*
Regalecus pacificus Haast, 1878, p.246, pl.7. Type locality: New Brighton, New Zealand.
Regalecus pacificus: Whitley, 1933, p.70, fig.2, and 1948, p.16, and 1962, p.64, unnumbered fig., and 1964, p.41, and 1968, p.45: Munro, 1957b, p.64, fig.451 (two figures so numbered): Marshall, 1964, p.125, pl.29, fig.136, and 1966, p.178, pl.29, fig.136.
Regalecus gladius: Günther, 1861, p.308: Allport, prior to 1882; Macleay, 1882a, p.55: Johnston, 1883, p.123, and 1891, *ibid.* (1890), p.34 (p.13 of reprint). *Non Gymnetrus gladius* Valenciennes, 1835.

PLATE 2 - *Regalecus pacificus* Haast, 1878. A specimen secured at Mersey Bluff Beach, Devonport, northwest coast, Tasmania by Mr D. Heywood in December 1977. Approximate total length 3 m. (Photo: *Advocate*.)

PLATE 3 - *Regalecus pacificus* Haast, 1878. A specimen found stranded by Mr K. Adamson and Mr N. Chilcott at Low Head, Tamar estuary, north coast, Tasmania in October 1981 (Q.V.M. Reg. No. 1981/5/58). Total length as preserved 3.55 m, estimated length when perfect 5.4-5.9 m. (Photo: *Examiner*.)

Regalecus glesne: McCulloch, 1921, p.34, pl.26, fig.125a: Lord, 1923, p.65, and 1927, p.13: Lord and Scott, 1924, pp.9,14, unnumbered outline fig.: McCulloch, 1929, p.138. *Non Regalecus glesne* Ascanius, 1772.

Regalecus banksii: M'Coy, 1887, p.169, pl.145: Lucas, 1890, p.32. *Non Gymnetrus banksii* Valenciennes, 1835.

Regalecus banksi: Marshall, 1964, p.125, and 1966, p.178.

Gymnetrus banksii: McCulloch, 1929, p.138: *Non Gymnetrus banksii* Valenciennes, 1835.

Regalecus argenteus Parker, 1883, p.520. *Nomen nudum.*

Regalecus argenteus Parker, 1884, p.284, pls 23,24. Type locality: Moeraki, Otago, New Zealand.

Regalecus argenteus Parker, 1888, p.20, pl.5.

Regalecus grillii: Forbes, 1891, p.192: McCulloch, 1929, p.138. *Non Gymnetrus grilfii* Lindroth, 1798.

Regalecus remipes: McCulloch, 1929, p.138. *Non Regalecus remipes* Brunnich, 1788.

Gymnetrus hawkenii: McCulloch, 1929, p.138. *Non Gymnetrus hawkenii* Bloch, 1795.

Regalecus masterii De Vis, 1891, p.13. *Nomen nudum.*

Regalecus masterii De Vis, 1892, p.109. Type locality: near Tweed River, Queensland.

Regalecus masterii: McCulloch, 1929, p.138.

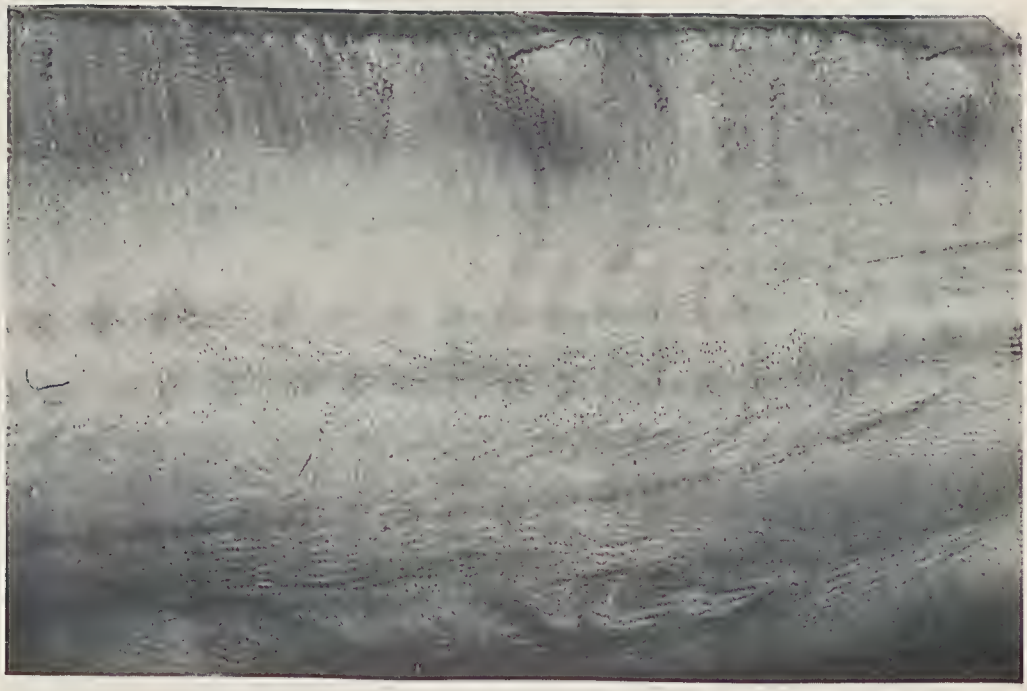

PLATE 4 - *Regalecus pacificus* Haast, 1878. Detail of portion of the posterior region of the Low Head specimen of which a general view appears in plate 3. Note especially paired markings along dorsal border (Q.V.M. Reg. No. 1981/5/55). (Photo: *Museum*).

Note on synonymy

While the decision taken in the Check-List (McCulloch 1929) to represent the Australasian oarfish by a taxon (*Regalecus glesne* Ascanius, 1772) bestowed on a northern hemisphere fish has inevitably led, given the mere nature of a checklist, to the formal introduction to the Australian taxonomic scene of some species names of only marginal significance, the main trend in the Australian literature has followed, with very few exceptions (the most noticeable being the adoption by M'Coy (1887), of Valenciennes' *R. banksii* — ascribed by M'Coy to Cuvier), a regular chronological trinomial sequence. In the last century local texts employed *R. gladius* Valenciennes, 1835 (based on "*Cepola gladius*" Walbaum, ascribed by authors, in accordance with the convention then current, to Cuvier and Valenciennes, with reference to Histoire Naturelle des Poissons); during the first three or four decades of the present century *R. glesne* Ascanius, 1775 was in general use; while in the more recent years the validity of Haast's *R. pacificus*, with type locality New Zealand, has been almost universally accepted. Two additional names for the Australasian form have been proposed, *R. argenteus* by Parker in New Zealand and *R. masterii* by De Vis in Queensland.

Recent strandings

Our knowledge of this deep-sea oceanic species is largely based on specimens cast up from time to time, often in a damaged state, on the beach. Günther (1880: 523) noted that not more than 16 strandings were recorded on the coasts of Britain between 1759 and 1878. The first record of a Tasmanian example in the formal literature is provided by Johnston (1883, p.123): "specimen examined, 14 feet [4.3 m] long, captured at the Penguin [town, on northwest coast, now simply known as Penguin], Tasmania". Lord and Scott (1924:

46, outline figure) state "A specimen secured in a fish trap at Stanley, a sketch of which is in the Tasmanian Museum, gives the dimensions as follows:— Length, 14 feet [4.3 m]; greatest depth, 12 inches [30 cm]; breadth, 2 to 3 inches [51-76 mm]". The total length is said to exceed 23 feet [7 m] (Whitley 1962). Further local strandings have from time to time been reported in the press, but no systematic list of these exists.

Two recent strandings are here recorded: these individuals are of some special interest, making unusual contributions to the curious problem of the color pattern in the Australasian oarfish.

(a) A specimen secured at the Mersey Bluff Beach, Devonport, northwest coast, in 1977. The *Advocate* of 8 December reported that Mr Don Heywood, a visitor from Chadstone, Victoria, noticed the fish splashing about in the shallows and dragged it out by hooking his thumbs in the gill slits; the length was given as 3 m. By courtesy of the editor of the newspaper, Mr D.J. Cherry, an excellent photograph of this fish is here reproduced (pl. 2)

(b) The *Examiner* of 14 October 1981 reported the finding by Mr Kerry Adamson and Mr Norm Chilcott, of Georgetown, of an example washed ashore, still fresh and bleeding, at Low Head, Tamar estuary, north coast; the length was given as 4 m (see below), the weight as ca.18 kg. This fish, the newspaper photograph of which (pl.3) together with a photograph taken later (pl.4) showing color pattern near the dorsal border of the trunk, is preserved in the Queen Victoria Museum, Launceston (Reg. No. 1981/5/58; listed as presented by J. Hooper).

Color pattern

Specimen (a). The conspicuous and extensive ornamentation of the Devonport specimen, well shown in the plate, exhibits some unusual features. It consists chiefly of closely set spots; near the middle of the length these are arranged in 4-5 rows, of which the upper 2 are the most prominent, those of the superior row, hard against the dorsal profile, being rounded or subelliptical vertically, those of the next row rounded or a trifle elongate longitudinally. In the anterior one-third or more the markings of the upper row tend posteriorly to assume the form of subvertical bars, with those behind the head narrowing to streaks. Apart from a few indistinct and irregular smudges for a head length or so behind the head the flank is without markings in its lower part, the height of this immaculate band being close to half the total height just behind the head, the proportion decreasing caudad to perhaps one-third at the hindmost point included in the plate (as the picture appeared in the newspaper it extended to the pointed end of the fish, the small additional section apparently lacking ornamentation). The most notable differences between this pattern and that of the specimen, 13 feet 7 inches (4.1 m) in length, taken in the sea between Tasmania and Victoria in 1878, and figured, as *R. banksii*, by M'Coy [this figure adopted as definitive by Marshall (1964, 1966) and — with some modifications, which, however do not involve the color pattern, by Whitley (1962)] are as follows: spots extending forward to head instead of being confined to posterior three-fifths; spots not extending to ventral profile; absence of the narrow parallel horizontal lines (6 in anterior part of trunk); absence of "about 19 vertical black streaks, half an inch [12-13 mm] in width, of variable length [that] cross the anterior half of the body." From the New Zealand type of *R. pacificus* as illustrated (Haast 1878, pl.7) it differs greatly in one positive character, presence of rounded spots, and in three negative characters, absence of longitudinal bars, of irregular oblique dark markings, of the line of inverted V-shaped markings along dorsal border. It contrasts sharply with the figure of *R. glesne* reproduced in McCulloch's New South Wales Catalogue (1921, pl.11, fig.125a) and with other representations of the European oarfish depicting it as wholly covered with small evenly distributed round spots. No color pattern is indicated in the local figures of Lord and Scott (1924, unnumbered fig. on p.46), Munro (1957b, fig.451), Scott *et al.* (1974, unnumbered fig. on p.98), the three texts, however, specifying dark wavy or irregular lines and spots.

Specimen (b). The Low Head individual exhibits one feature of much interest, the presence along the whole length of the dorsal border of a series of closely set vertically elongate markings each consisting either of two subparallel dark bars, or, more particularly towards the hind end of the fish as preserved, of two outwardly convex arcs converging at the upper end or meeting there to form a narrow lancet arch — similar markings are shown in Haast's plate of his type but are not evident in any Australian figure to come under notice. This ornamentation is clearly apparent in pl.3 and is depicted in detail in pl.4. The width of the pier of the arch is commonly somewhat less than its distance from its fellow and more noticeably less than the distance between adjoining arches. Shortly behind the head, where the total depth is 260, the height of the marking is 55, its maximum width 15; at the truncated end of the specimen, where total depth is 150, the height decreases to 40, the width remaining much the same. In different parts of the body the arch ranges from light to dark grey, the interspaces then usually very pale grey or pearl, or, particularly posteriorly, from light to moderate brownish (at times with a reddish tinge), the lighter interspaces sometimes in part, especially superiorly, suffused with pale brownish. The remainder of the pattern is intermediate between that in local illustrations, the lower of the longitudinal stripes resembling the narrow lines in M'Coy's plate, the broader upper approximating the dark bands in Haast's plate, with, however, the uppermost including in it a sequence of dark spots, more regularly arranged than those in the former figure, approaching those of our Devonport specimen. A very slender black line, not evident in any representation of the fish, delimits the dorsal border throughout the length.

General features

Some general features of specimen (b) may be noted. Length: the total length as preserved is approximately 3.55 m, the hinder portion being missing beyond a point at which the depth is 150 or 0.58 depth near pelvic insertion. Examination of published figures suggests such a proportional depth could be expected to occur at around about 0.6-0.65 of the total length, the possible intact length of the present individual being 5.4-5.9 m. These length values would yield depth (maximum 300) in length 18-20 (M'Coy 22, Munro 23-30) and head (damaged, estimated length 240) 23-25 in length (M'Coy 22, Munro 21). Orbit: longer than high, 42 x 35 or 5.7 (M'Coy 5.0) in head. Dorsal rays behind crest: slender, acuminate, tolerably flexible, largest measured 78. Dorsal crest: the elongate anterior rays of the dorsal forming the characteristic cephalic crest would appear to number about 8 in specimen (a), the first 4 the stouter; however, a definitive count is not possible. In (b), in which only the bases of the rays remain in all except one (and that, a slender, highly flexible lash, imperfect at a length of 165 mm) the sequence is: 1st (just possibly 2nd), stout, basal diameter >2 mm; 3rd fine, diameter >1 mm; 4th-6th (?+), diameter ±2 mm. The dorsal profile above the anterior part of the head shows a remarkable diversity of patterns, some of which were assembled by Parker (1884, pl.24). As illustrated the dorsal fin may or may not be differentiated to form a crest, which may be single or may consist of two sections or sheaves; it may be highest in front, or near the middle, or may present two peaks: rays may be simple, spatulate, distally lobate or noded or some combination of these conditions. Some variants are noted below.

(a) No distinct crest. M'Coy (1887, pl.145) — a modification of M'Coy by Whitley (1962, unnumbered fig. on p.64) has a falcate outline (base exceptionally long, extending well behind head), with possible indication on hind border of base of about a dozen rays; Parker (pl.24, fig.8). (b) Crest a single sheaf. Haast (1878, pl.7), 8 simple rays of variable height; Parker (pl.24) 1 (7th ray) simple (fig.5), 11, decreasing caudad, simple (fig.4), 10, all spatulate except 2nd, 4th highest (fig.4); Lord and Scott (1924, unnumbered outline figure on p.46) 9 simple rays, highest anteriorly; Munro (1957b, right hand figure of two numbered 451), also Scott *et al.* (1974, unnumbered figure on p.98), 8 simple or somewhat lobate distally, decreasing caudad. (c) Crest distinguishable into two sections. The type of *R. argenteus* Parker, 1884 would seem to belong here, the general view of the head (pl.24, fig.1) showing, in succession caudad, 5 intact simple rays decreasing backwards, 4 stouter rays (2 imperfect), 7th and 9th with small foliate distal appendages, in 7th together with an irregular membranous fringe on posterior edge of shaft (detail of ray in fig.2), these 9 rays followed by bases only of 6 others; Parker (pl.24, fig.6)

5 simple, decreasing caudad, 7 (1st tallest in fin) with small lanceolate distal appendage, decreasing caudad; McCulloch (1921, pl.26, fig.125a), a similar arrangement; Whitley (1933, fig.2; separate figure of head of a New Zealand specimen) 5 simple, decreasing caudad, 9 (1st tallest in fin) regularly noded, about a dozen nodes in tallest ray, this figure reproduced in Handbook (Munro 1957b, left hand figure of two numbered 451) (shaft of pelvic also noded). The occurrence of this curious range of pattern in the cephalic section of the dorsal fin, to which our specimen (b) adds yet another variant, remains without apparent explanation.

Pectoral: represented only by 12 stout stumps, anterior border of base in advance of level of opercular border by about one-third eye diameter. Pelvics: imperfect, reduced to somewhat compressed rigid vitreous rods (length 85, 95), basal diameter 7, inserted in contiguous fleshy sacs 15 in diameter, behind head by about an eye diameter. Maxillary plate: elongate subtriangular, length 75, 2.2 (Munro "twice") width, 33. Preoperculum (only other opercular bone intact): vertical extent 55, longitudinal 110, chord 95. Tuberculation: the integument is everywhere tuberculate, the size and density of the tubercles varying irregularly somewhat at different parts of the length, but disposed in a more or less regular fashion at a given region (pl.4), the sequence from the dorsal profile downwards being, briefly before the end of the specimen as preserved, as follows. In the upper two-fifths of the flank — this band including and extending somewhat below the paired markings — the tubercles of the upper part are small, numerous, irregularly disposed, $>20/cm^2$, those further down tending to become arranged in vertical lines along and between the markings; in the half of the flank below, in which 4 or 5 low longitudinal ridges are developed (bearing the dark bands visible in pl.3), the tubercles tending to be flatter and larger on these, about $12\text{-}15/cm^2$, than on the interpsaces. In the upper part of the ventral one-tenth they become very numerous, minute, $40\text{-}50/cm^2$, while below them are 2-3 rows of stout closely set mammilliform processes, 14-16 in a line of 50 mm; the free downward projection of some of these results in the ventral profile being denticulate a condition clearly apparent in Haast's plate of the type and in some representations of the palaearctic species, e.g. Goode and Bean (1895, pl.117, fig.395).

Family CARANGIDAE

Up till 1978 four members of this family (which has at various times been, partly or wholly, designated Seriolidae, Juvenellidae, Nematistidae) currently regarded as valid species were known to occur in Tasmanian waters: *Naucrates ductor* (Linné, 1758), *Seriola grandis* Castelnau, 1872, *Usacaranx nobilis* (Macleay, 1881), *Trachurus declivis* (Jenyns, 1841). The synonymy of twice as many names occurring in the local faunal lists was sorted out in Part XXV (1979), which also provided a key to the authentic Tasmanian assemblage: it was there incorrectly stated that Castelnau's species escaped the notice of the Check-List (McCulloch 1929). In that paper a fifth species was added, *Trachurus novaezelandiae* (Richardson), there reported as *Trachurus mccullochi* Nichols, 1920.

Genus *TRACHURUS* Rafinesque, 1810

Trachurus Rafinesque, 1810, p.41. Type-species, *Trachurus saurus* Rafinesque = *Scomber trachurus* Linné.

Trachurus novaezelandiae Richardson, 1843

Saurel de la Nouvelle-Zéland Cuvier (*in*: Cuvier and Valenciennes), 1833, p.26; *non binomen*.
Trachurus novaezelandiae Richardson, 1843a, p.21 = Cuvier, 1833. Type locality: New Zealand.
Trachurus novaezelandiae McCulloch, 1921, p.62: Stephenson and Robertson, 1977, p.251, figs 1-3.
?*Scomber clupeoides*: Richardson, 1843a, p.26, and *in*: Trav. N.Z. (Diffenbach), 1843b, p.210, *ex* Solander MS. Type locality: Dusky Bay, New Zealand.
?*Trachurus clupeoides*: Whitley, 1968, p.57.
Caranx trachurus japonicus Temminck & Schlegel, 1844, p.109, fig.1.

Type locality: shores of Japan.

Trachurus declivis: McCulloch, 1915, p.125, fig.34(2); Wakiya, 1924, p.146: Griffin, 1932, p.124, fig.18. *Non Trachurus declivis* Jenyns, 1842.

Trachurus japonicus: Nichols, 1920, p.479: Wakiya, 1924, p.144: Aleev, 1957, p.220, fig. 4: Suzuki, 1962, p.213.

Trachurus mccullochi Nichols, 1920. p.479; new name for *Trachurus declivis*: McCulloch, 1915; *non Trachurus declivis* Jenyns, 1842. Type locality: mouth of Wide Bay, Queensland; Investigator Strait, South Australia (*Endeavour*).

Trachurus mccullochi Munro, 1958c, p.124, fig.808: Berry and Cohen, 1974, p.194: Scott, 1979, p.121.

Trachurus trachurus: M'Coy, 1878, p.25, pl.18.

Additional Tasmanian material

This species was added to the Tasmanian faunal list in Part XXV (1979) on the basis of a specimen, *Ls* 283, taken by Mr M. Watson in the Tamar estuary, north coast, during an Apex fishing contest, 26 February 1978 (Q.V.M. Reg. No. 1978/5/63). At the 1981 contest 29 March, two further examples were entered in the section Most Unusual Fish: (a) *Ls* 262, *Lt* 293, Miss K. Walker (Q.V.M. Reg. No. 1981/5/49) (b) *Ls* 267, *Lt* —, Mr R. Collins (1981/5/43). In April three examples taken by Mr J. Stockton in a fish trap at Penguin, north-west coast, were submitted to the Museum for identification; these were not retained, but a series of routine measurements was made on one specimen, (c) *Ls* 287, *Lt* 340. The 1978 specimen was reported as *Trachurus mccullochi* Nichols, 1920. In a recent review of the New Zealand representatives of the genus Stephenson and Robertson (1977) regard this as synonymic with *T. novaezelandiae* Richardson, 1843. Some of their nomenclatural conclusions are noted above. The acceptance of this status extends its distribution from temperate Australian waters to the shores of much of southeastern Asia.

Ventral rays

It was noted of the first recorded Tasmanian example "The ventral rays are somewhat unusual in increasing from 1st — farthest from spine, see Part XIX (1974) — to 5th; in a more common pattern 4th exceeds 5th". This departure from the modal pattern proves to be an individual peculiarity, the longest ventral ray in specimens (a) and (b) — no data available for (c) — being the customary 4th. The equations for these two examples with L = their serial numbers {1,2,3,4}, with logarithms of both sets of magnitudes taken are as below:

Log L = 0.4604 log N + 1.8495; t 20.763**; estimated (measured) lengths, *TLs*, 71(70), 97(99), 117(119), 134(131).

Log L = 0.4631 log N + 1.8282, 67(66), 93(97), 112(116), 128(124).

Family SCOMBRIDAE

Brief notes on the family are given in Part XXV (1979) and Part XXVII (1981).

Genus *GASTEROCHISMA* Richardson, 1845

Gasterochisma Richardson, 1845, p.346. Type-species, *Gasterochisma melampus* Richardson.
Lepidothynnus Günther, 1889, p.15. Type-species *Lepidothynnus huttonii* Günther.

Gasterochisma melampus Richardson, 1845
(Text-figs 1-6)

Gasterochisma melampus Richardson, 1845, p.346. Type locality: Port Nicholson, New Zealand.

Gasterochisma melampus: Scott, 1981, p.135 (references and synonymy).

Additional material

Four occurrences in Tasmanian waters of this "very rare oceanic species" (McCulloch 1922: 104) have been reported, all in this journal: Derwent estuary, *Ls* 838, *Lt* 991 (Johnston 1883 and *in:* Whitley 1929), Falmouth, *Ls* 372 *Lt* 459 (Scott 1979),

Binnalong Bay, *Ls* 460 *Lt* 578 (Scott 1981), off mouth of Mersey, *Ls* 342 *Lt* 417 (Scott 1981). A fifth example, *Ls* 234 *Lt* 292, found stranded between Greens Creek and Brooks Creek on 10 March 1981 by an Earthwatch expedition to the West Coast (Q.V.M. Reg. No. 1981/5/81) is here noted.

Proportions

A number of body proportions of the present specimen, here marked with an asterisk, fall outside ranges previously reported — 1981 range shown in parentheses together with the specification, where available, given by the Handbook (Munro 1958a). Greatest depth in standard length 3.4* (3.6-3.9, 3.9-4.1). Head in standard length 3.8* (3.9-4.0, 4-4.1). Depth of caudal peduncle in head 6.4 (6.4-6.8). Eye in head 6.1 (7.8-8.4, 5.5-7.4), in snout 2.3* (3.0-3.1). Pectoral in standard length 7.9* (6.0-6.6), in head 2.1* (1.5-1.6). Ventral in standard length 2.8* (2.9-3.6), in head 1.4 (1.3-1.4). First dorsal base in standard length 3.4 (3.0-3.4), second dorsal base 8.2 (8.0-11.0), anal base 14.6* (10.7-13.0).

Variation with growth

It has long been known that this species exhibits significant variation during growth, including a remarkable decrease in the relative size of the ventral, an increase in the relative length of the pectoral and an inversion in the relative heights of the dorsals, the anterior fin being the higher in juveniles the posterior in adults. In Part XXVII (1981) data relating to these features were collated for the three examples reported in these contributions, together with the type-specimen, *Lt* 203, Johnston's example, a New Zealand specimen, *Lt* 1 637, from Kaikoura (Waite 1912) and the *Challenger* fish, *Lt* 1 644, type specimen of *Lepidothynnus huttoni* Günther, 1889. It was found the characters are significantly linear on *Lt*. Summary results, with the inclusion of the present example, are set out below; all dimensions in thousandths of total length.

Lt	203	292	417	459	578	991	1 637	1 644 mm	
Ventral: measured	331	363	264	284	270	147	97	71	r — 0.966 (z — 2.034)
estimated	332	316	294	286	265	190	74	69	
Pectoral: measured	110	124	127	123	133	135	149	168	r 0.921 (z 1.593)
estimated	112	120	124	125	128	140	158	158	
Dorsal ratio: measured	2.6	2.3	2.0	1.5	1.2	—	0.7	0.5	r — 0.901 (z — 1.477)
estimated	2.2	2.1	1.9	1.9	1.7	—	0.5	0.5	

For the best straight lines for the equation feature on *Lt* the slopes are — 0.180, 0.0279, — 0.00114, the intercepts 369, 112, 24.

Dorsal and ventral profiles and overall outline

Ten measurements of height above or depth below an axis from snout tip to middle of caudal peduncle at hypural joint, together with their sum, taken at equal intervals and recorded as thousandths of standard length; with parameters of the relevant equations of the form $Y = A + BN + CN^2 + DN^3 + EN^4$ (N = serial number of measurement caudad) and estimates derived from these are set out in table 1.

Finlets

In the 1981 communication an investigation of the relative location, length and height of the dorsal and anal finlets was made with data for the Mersey individual, which was there first reported. In the largest individual, from Binnalong Bay, the finlets have suffered some distortion (probably as the result at some stage of temporary dessication), and dimensions other than the heights of the anal finlets cannot usefully be measured. Data for the Falmouth specimen are here reported along with those for the present West Coast example: they are found to be consonant with the data for the Mersey fish.

(a) Location of finlets. With the anterior point of insertion of the hindmost finlet taken as origin and successive distances back to the anterior insertions of the earlier finlets measured it is found these distances are an exponential function of the reverse

TABLE 1

CASTEROCHISMA MELAMPUS Richardson, 1845

Contour of finlets (y) as a function of body contour (x). Parameters of $y = mx + c$ for deciles (1-4) and deciles (6-9) of dorsal and anal finlet height on corresponding deciles of dorsal profile above, and ventral profile below, longitudinal body axis from snout tip to caudal peduncle at hypural joint. Three Tasmanian specimens: all dimensions as millesimals of standard length.

Ls	Region	Set	m	c	t	Estimated (measured) height of finlet
		(1-4)	0.0974	−4.257	18.534**	4.31(4.27) 7.43(7.50) 10.06(9.30) 9.96(10.70)
	Dorsal	(6-9)	0.0291	9.078	42.542***	12.83(12.80) 12.25(12.26) 11.20(11.25) 10.18(10.15)
		(1-4)	0.0876	−5.172	17.213**	4.28(4.27) 6.91(6.61) 8.93(8.92) 10.06(10.21)
234	Ventral	(6-9)	0.00622	11.946	1.434	12.92(12.60) 12.85(13.02) 12.53(12.89) 12.21(12.00)
		(1-4)	0.1303	−1.043	11.476**	6.96(6.70) 10.38(10.95) 13.05(12.80) 14.01(13.95)
	Dorsal	(6-9)	0.0281	11.013	23.632**	14.13(14.20) 13.89(13.80) 12.98(13.00) 12.00(12.00)
		(1-4)	0.0969	−1.821	33.206***	6.96(7.00) 11.79(11.60) 13.34(13.50) 14.82(14.80)
372	Ventral	(6-9)	0.0253	10.819	8.092**	14.73(14.70) 14.14(14.35) 12.97(12.65) 11.71(11.85)
		(1-4)	0.0940	1.094	—	— (8.33) — (—) — (—) — (14.25)
	Dorsal	(6-9)	0.0300	10.990	29.583**	14.95(15.00) 14.23(14.20) 13.21(13.15) 12.25(12.30)
		(1-4)	0.0401	4.326	10.194**	7.68(7.80) 9.69(9.18) 10.05(10.06) 10.33(10.70)
342	Ventral	(6-9)	0.0162	10.290	7.891*	12.43(12.30) 11.94(12.10) 11.25(11.30) 10.68(10.60)

(i.e. cephalad) serial numbers of the finlets, N'; $\log L = k \log N' + \log b$,

(I) Dorsal. For the dorsal finlets of the present specimen k = 0.9596, $\log b$ = 1.5911, t 86.549***; estimated (measured) distances 39(38), 76(76), 112(114), 147(150), 183(182), 218(214). Parameters for the Mersey example reported on earlier 0.9943, 1.0391, t 50.578***, for the Falmouth individual 1.2003, 1.4300, t 59.432***. It will be noted that while the slopes for the largest and smallest examples are tolerably comparable (that of the latter being 0.965 of the former), that of the intermediate specimen is much greater than that of either of the others (1.207 smallest). A similar situation obtains for the anal finlets (parameters below).

(II) Anal. For the present specimen k = 0.9002, $\log b$ = 1.5825, t 50.842***; estimated (measured) distances 38(38), 71(73), 103(105), 133(134), 163(159). Mersey, 0.9660, 1.4883, 33.538***; Falmouth, 1.2671, 1.2729, 131.197***.

(b) Length of finlets. With increasing development of a posterior process, finally assuming a pennon-like form, the lengths increase caudad. In a loglog plot they are linear on reverse serial number, N'.

(I) Dorsal. For the present specimen $\log L = -0.2666 \log N' + 1.6643$; t 8.939***; estimated (measured) lengths 27.5(25.6), 28.6(27.8), 30.1(31.2), 31.9(34.3), 34.4(35.5), 38.4(38.5), 46.2(43.4); parameters for earlier specimens, Mersey −0.4722, 1.8413, t 48.353***; Falmouth −0.2788, 1.7736, t 26.860***.

(II) Anal. $\text{Log } L = -0.3422 \log N' + 1.7391$; t 28.391***; 30.0(29.1) 31.6(32.1), 34.1(34.2), 37.7(38.5), 43.3(42.7), 54.8(54.7). Mersey −0.4323, 1.8148, t 31.151***; Falmouth −0.3652, 1.8014, t 29.008***.

(c) Height of finlets. The finlets initially increase regularly in height then regularly decrease. From a consideration of finlet height in the Mersey specimen in Part XXVII (1981) there emerged the highly interesting fact that the contours of the finlet series and of the body are strongly correlated, dorsal body with dorsal finlets, ventral body with anal finlets, each with markedly different anterior and posterior segments: it was then observed such form-patterns may well have significant biological and hydrodynamic implications not at present apparent.

The relationships of the two outlines have now been further examined, attention being given also to the present specimen and the Falmouth fish (in the largest (Binnalong) individual some local deformation, probably occasioned by temporary dessication, precludes the making of satisfactory finlet height — and of finlet interspace — while in the Falmouth fish the second dorsal finlet is imperfect). Data in table 2.

TABLE 2

CASTEROCHISMA MELAMPUS Richardson, 1845

Dorsal and ventral profiles and overall outline of four Tasmanian examples. Ten measurements of height above or depth below an axis from snout tip to middle of caudal peduncle at hypural joint, together with their sum, taken at equal intervals and recorded as thousandths of standard length, with parameters of the relevant equations of the form $Y = A + BN + CN^2 + DN^3 + EN^4$ (N = serial number of measurement caudad) and estimates derived from these.

La,mm	Region	*A*	*B*	*C*	*D*	*E*	*R*	Estimated (measured) height or depth, *TLe*
	Dorsal	45.8	47.35	−3.942	−0.5636	0.04618	0.9927	89(88) 124(120) 141(147) 147(146) 132(133) 126(129) 102(109) 73(73) 44(38) 23(26)
	Ventral	87.2	13.56	9.303	−2.2881	0.111568	0.9911	108(106) 135(138) 159(161) 173(174) 174(165) 154(156) 131(145) 93(94) 54(43) 22(26)
234	Overall	132.9	61.09	5.224	−2.8198	0.15977	0.9923	197(194) 256(258) 300(308) 321(320) 316(298) 285(285) 233(255) 167(167) 98(81) 44(51)
	Dorsal	35.7	25.15	1.848	−0.9529	0.04936	0.9946	62(61) 87(88) 106(108) 118(116) 119(144) 111(111) 94(102) 70(70) 40(35) 13(15)
	Ventral	72.0	134.9	13.238	−3.2140	0.17026	0.9869	96(91) 130(140) 159(156) 175(172) 175(170) 156(155) 122(132) 87(85) 40(35) 19(15)
342	Overall	92.2	612.5	5.693	−2.7343	0.14835	0.9947	157(152) 218(228) 266(265) 291(287) 291(284) 266(266) 218(234) 152(155) 85(70) 23(29)
	Dorsal	39.0	40.98	−0.618	1.0280	0.06671	0.9993	78(77) 111(117) 134(132) 144(140) 142(137) 127(132) 103(108) 74(74) 46(62) 20(27)
	Ventral	56.0	30.48	6.035	−2.3592	0.14190	0.9931	90(86) 124(136) 150(145) 160(152) 153(155) 130(132) 97(102) 60(59) 30(24) 24(27)
372	Overall	257.5	−93.117	18.724	−1.99027	0.079865	0.9981	168(163) 247(253) 285(277) 297(292) 292(292) 270(263) 212(210) 134(133) 68(66) 57(54)
	Dorsal	50.6	46.12	−9.149	0.6891	−0.02695	0.9893	88(87) 111(114) 123(125) 126(126) 122(117) 112(111) 97(104) 76(84) 50(40) 18(22)
	Ventral	66.8	25.71	5.286	−1.8355	0.099942	0.9829	96(91) 127(138) 150(149) 163(155) 161(155) 144(143) 116(135) 80(77) 44(32) 16(22)
460	Overall	116.4	−4.591	−1.0387	0.06789	0.06789	0.9075	184(178) 237(252) 272(274) 287(281) 281(272) 254(253) 211(239) 155(162) 93(72) 30(44)

In figures 1-3 the body and finlet profiles are shown side by side. Heights of the body outline above and its depth below a line joining snout tip to middle of caudal peduncle at hypural joint taken as 10 equal intervals are shown in table 1. To obtain 10 comparable entries from 7 or 8 finlets the measured heights have been plotted against abscissae marked off in intervals proportional to distances between individual finlets, and ordinates measured from the graph for 10 equidistant abscissae; these values then being arbitrarily scaled up (by a factor of 6) to make the finlet curve of the same order of magnitude as the body curve. It is seen the two curves exhibit considerable resemblance, with the anterior portions more or less parallel, but the posterior portions divaricating backward.

In figures 4-6 the ordinates of the finlet deciles are plotted against the body deciles. To obtain these 10 comparable entries from 7 or 8 finlets the measured heights were plotted against abscissae marked off at intervals proportional to distances between individual finlets (as in figs 1-3), and ordinates measured from the graph for 10 equidistant abscissae. Deciles {1-4} and {6-9} show a strong tendency to be linear; with deciles 5, 10 less constant in position. Of the {12-1} such lines (Falmouth dorsal) decile set {1-4} with only 2 variates) 1 only fails to yield a formally significant correlation (West Coast {6-9} with r 0.712, z 0.891) 4 of the remainder being significant at levels better than 5%, 6 at better than 1%; mean values for dorsal finlets (two 4-member sets pooled) r 0.993 (z 2.811) for anal finlets 0.939 (1.727). The relevant data are set out in table 2. It may be noted the correlation noted earlier for the Mersey specimen was that between the anterior 4 and posterior 4 of the 8 finlets with the anterior 4 and posterior 4 of the 10 body measurements; not, as here, between the latter and the anterior 4 and posterior 4 of the decile finlet heights derived from the curves in figs 4-6.

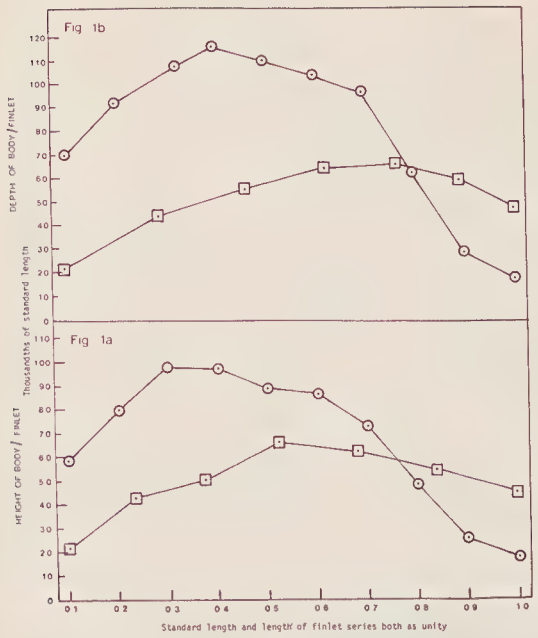
Fig 1b
Fig 1a
DEPTH OF BODY/FINLET
HEIGHT OF BODY/FINLET
Thousandths of standard length
Standard length and length of finlet series both as unity

FIG. 1 - *Gasterochisma melampus* Richardson, 1845. a: Height of dorsal profile above a mediolateral anteroposterior axis, and height of dorsal finlets. b: Depth of ventral profile below same axis, and height of anal finlets. All dimensions as thousandths of standard length; profiles circles, finlets squares. Specimen standard length 234 mm, from west coast, Tasmania.

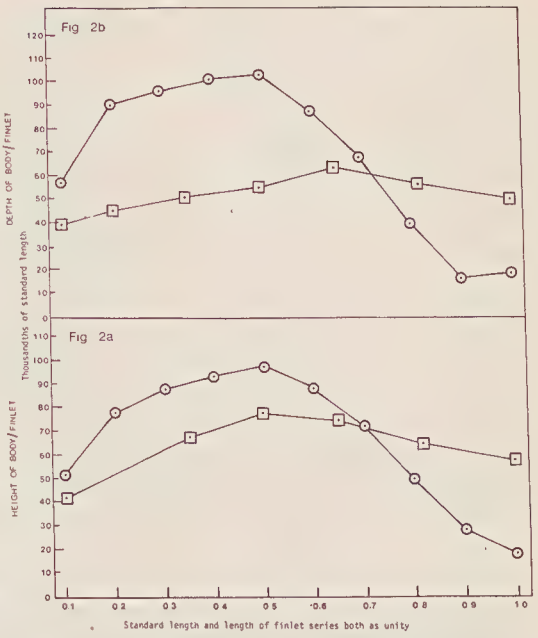
Fig 2b
Fig 2a
DEPTH OF BODY/FINLET
HEIGHT OF BODY/FINLET
Thousandths of standard length
Standard length and length of finlet series both as unity

FIG. 2 - *Gasterochisma melampus* Richardson, 1845. a: Height of dorsal profile above a mediolateral anteroposterior axis, and height of dorsal finlets. b: Depth of ventral profile below same axis, and height of anal finlets. All dimensions as thousandths of standard length; profiles circles, finlets squares. Specimen standard length 372 mm, from Falmouth, east coast, Tasmania.

Individual variation in body form

Measurements of height of body above and depth below an anteroposterior axis from snout tip to middle of caudal peduncle at 10 equal intervals have been made on our four specimens (including the Mersey example reported on earlier). These dimensions, as thousandths of standard length, are shown in table 1, where they are fitted with 4° polynomials.

Individual variations may be further examined by comparisons of the sums of the decile heights and depths of the anterior and posterior halves of the dorsal profile, the ventral profile and the overall outline. In all save 1 of the 27 subsets the relative heights and depths of the smallest exceed those of the other specimens. In the largest individual but one the anterior portion of the dorsal profile is lower, while the posterior portion is higher, than in the rest. Individual differences of the local dimensions can result in other appreciable differences in general appearance. Thus for the ratio anterior half/posterior half of the dorsal profile the value for the Falmouth individual is decidedly less than values for the others while for the same ratio for the ventral profile is the highest. The Mersey individual is lower than the rest in the region of the first two deciles also in the region of the last two deciles; further, the total for the 10 dorsal measurements is the lowest. The caudal peduncle region exhibits noticeable variation, the penultimate measurement in seven instances being 1.5-2.3, $\bar{x}$ 1.8 times the last, but in one instance only 0.9 of it.

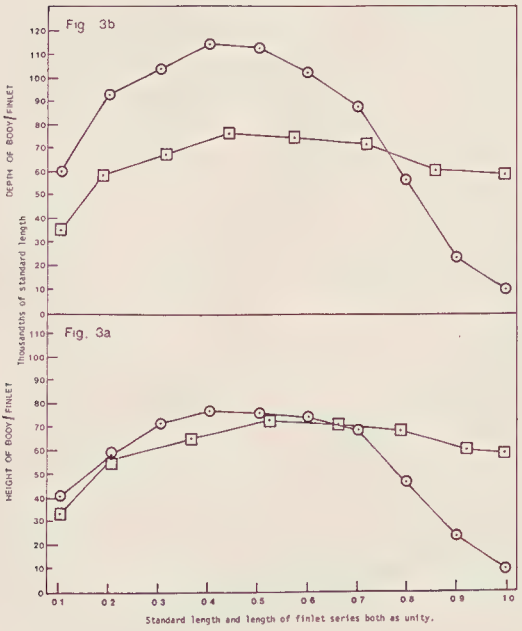
Fig 3b
DEPTH OF BODY / FINLET
Thousandths of standard length
Fig. 3a
HEIGHT OF BODY / FINLET
Standard length and length of finlet series both as unity.

FIG. 3 - *Gasterochisma melampus* Richardson, 1845. a: Height of dorsal profile above a mediolateral anteroposterior axis, and height of dorsal finlets. b: Depth of ventral profile below same axis, and height of anal finlets. All dimensions as thousandths of standard length; profiles circles, finlets squares. Specimen standard length 342 mm, from off Mersey River, northwest coast, Tasmania.

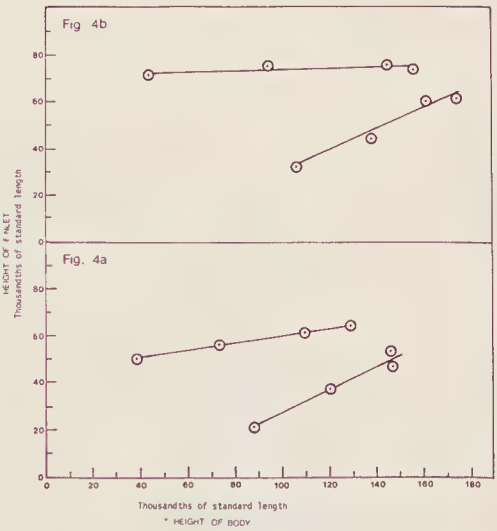

FIG. 4 - *Gasterochisma melampus* Richardson, 1845. a: Height of dorsal finlets, read off as deciles from fig. 1a, plotted against decile heights of dorsal profile above a mediolateral anteroposterior axis. b: Height of anal finlets, read off as deciles from fig. 1b, plotted against decile depths of ventral profile below same axis. Specimen standard length 234 mm, from west coast, Tasmania.

Within the range of the sample, in the dorsal profile the anterior half is markedly more variable than the posterior (*V* 18.7, 5.9), while in the ventral profile the reverse obtains (*V* 12.2, 6.3). With dorsal and ventral profiles combined the anterior portion is about half as variable again as the posterior (*V* 9.6, 6.0).

General features

Some general features subject to individual variation are here specified for the West Coast fish. D. XVII; I, 9 (last two rays finlet-like); 7 finlets. A.I, 10 (hinder rays increasingly finlet-like); 7 finlets. P. I, 20. C. 6/24/7. L.l. *ca* 54, terminating on right side below last one-sixth of anal base, on left below first finlet. L. tr. 8 + *ca* 19. Operculum smooth; several obscure scales near upper border. Preoperculum fully scaled; 6 rows beneath eye. Scales on occiput ceasing above first two-fifths of eye on left side, about first one-tenth on right. No distinct corselet, but about 5 rows of scales below pectoral base larger than adjacent scales. Some 8-9 rows of scales behind operculum above pectoral base sloping obliquely forward and upward. No definite peduncular keel: two raised lines extending forward for nearly a head length from level of last finlet (possibly post-mortem). Maxilla to below middle of eye.

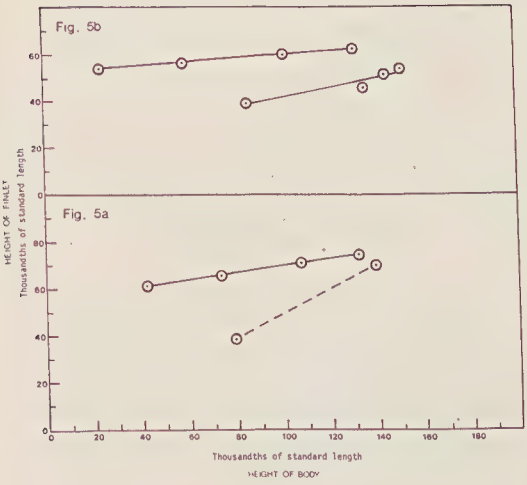

FIG. 5 - *Gasterochisma melampus* Richardson, 1845. a: Height of dorsal finlets, read off as deciles from fig.2a, plotted against decile heights of dorsal profile above a mediolateral anteroposterior axis. b: Height of anal finlets, read off as deciles from fig.2b, plotted against decile depths of ventral profile below same axis. Specimen standard length 372 mm, from Falmouth, east coast, Tasmania.

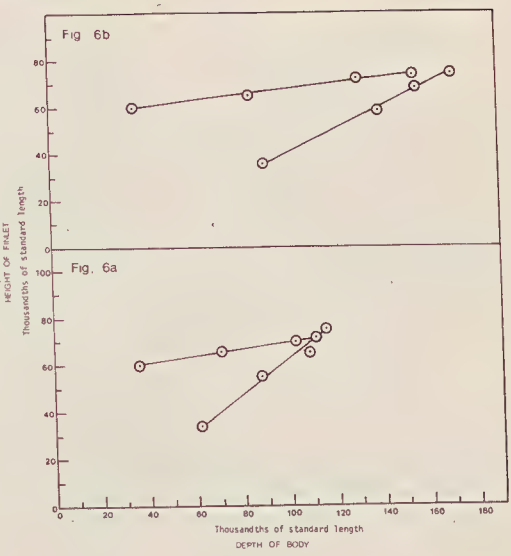

FIG. 6 - *Gasterochisma melampus* Richardson, 1845. a: Height of drosal finlets, read off as deciles from fig.3a, plotted against decile heights of dorsal profile above a mediolateral anteroposterior axis. b: Height of anal finlets, read of as deciles from fig.3b, plotted against decile depths of ventral profile below same axis. Specimen standard length 342 mm, from off Mersey River, northwest coast, Tasmania.

Coloration

Trunk and tail plumbeous above midlateral line, more or less silvery below. Head mainly like trunk, but naked portion mostly more or less flesh-colored, blackish on dorsum of snout. First dorsal translucent, colorless or faintly yellowish; second dorsal and anal with a very dark brownish streak covering proximal half or two-thirds of each ray, pale yellowish. Dorsal and anal finlets mostly yellowish, with small anterior proximal patch of melanin pigmentation breaking up distally into diffuse chromatophores. Pectoral pale greenish yellow, rays darker. Ventral black or blackish.

Observations on some Tasmanian fishes: Part XXVIII

Family BOVICHTHYIDAE

Three Australian species are commonly accommodated in this small family: (a) *Pseudaphritis bursinus* (Cuvier, 1830), appearing in most of the recent local texts as *P. urvillii* (Valenciennes, 1831); (b) *Bovichtus variegatus* Richardson, 1846; (c) *Bovichtus angustifrons* Regan, 1913, the validity of which would seem to be open to some doubt. Though (a) was originally associated by McCulloch (1922) with (b) and (c), later in the Check-List (1929) he placed it in the monotypic family Pseudaphritidae: earlier writers had referred these two genera to Trachinidae (Günther 1880, Johnston 1883, 1891) or to Nototheniidae (Boulenger 1910). All three species occur in Tasmania, which provides the locality for one of the two specimens on which (c) was based (source of other unknown); while this State, *fide* McCulloch (1929), is the type locality of *P. urvillii*.

Subsequently to the emendation by Agassiz (1845) of the name of the type genus *Bovichtus* Valenciennes, 1831 to *Bovichthys* the familu name has assumed several variant forms (at times — e.g. Lord and Scott (1924) — more than one in the same publication) including Bovictidae, Bovichtidae, Bovicthiidae, Bovichthyidae, the last-named receiving the imprimatur of Greenwood *et al.* (1966) in their provisional classification of living teleosts. A key to the Tasmanian members of the family appears in Part VI (1953), which provides some meristic and morphometric data on a sample of juveniles of *Bovictus variegatus*, further notes on this species being given in Part VIII (1957); observations on *Pseudophritis bursinus* (as *P. urvillii*) are reported and discussed in Part IX (1960).

Genus *PSEUDAPHRITIS* Castelnau, 1872

Pseudaphritis Castelnau, 1872, p.92. Type-species, *Pseudaphritis bassii* Castelnau, 1872 = *Eleginus bursinus* Cuvier, 1830.
Aphritis Valenciennes, 1831, p.483. Tyep-species, *Aphritis urvillii* Valenciennes, 1831 = *Eleginus bursinus* Cuvier, 1830. Preoccupied by *Aphritis* Latreille, 1804 (Diptera).
Phricus Berg, 1895, p.65 (substitute name for *Aphritis* Valenciennes, 1831; preoccupied as above).

Pseudaphritis bursinus (Cuvier, 1830)
(Text-figs 7-9)

Eleginus bursinus Cuvier, 1830, p.161. Type locality: Port Jackson (Quoy & Gaimard).
Aphritis urvillii Valenciennes, 1831, p.484, pl.243. No locality (D'Urville) [= Tasmania, *fide* McCulloch 1929, p.337].
Aphritis urvilli: Allport, prior to 1882 (MS): Johnston, 1883, p.116.
Uphritis urvillii: Johnston, 1891, pp.25,33 (reprint, 1891, pp.4,12).
?Eleginus bursinus: Ogilby, 1898, p.560: McCulloch, 1929, p.337 (in synon.).
Pseudaphritis bursinus: Scott, 1962, p.238: Whitley, 1964, p.53.
Pseudaphritis bassii Castelnau, 1872, p.92 (in specific diagnosis, p.92, second binomen rendered *bassü*, typographical error for *bassii*; correctly rendered in index to paper, p.240). Type locality: the Straits of Bass [now Bass Strait].
Pseudaphritis bassii: Macleay, 1881b, p.565: Lucas, 1890, p.26: McCulloch, 1929, p.337 (in synon.; p.72 in Castelnau cited in error for 92).
Aphritis bassi: Ogilby, 1890, p.68.
Aphritis dumerili Günther, 1874, p.91 [Based on *Pseudaphritis bassii* Castelnau, 1872 — *dumerili* presumably a *lapsus calami* for *durvilli*, an erroneous version of *urvillii* Valenciennes, 1831, used elsewhere by Günther (1861, *Ann. Mag. nat. Hist.*, 3(7), p.88)].
Pseudaphritis urvillii: Macleay, 1881, p.565: Ogilby, 1898, p.560: Hale, 1920, p.25: Waite, 1921, p.141, fig.221 and 1923, p.164, unnumbered fig. and 1924, p.482, pl.30, fig.1: McCulloch, 1922, p.103, pl.47, fig.283a and 1927, p.77, pl.32, fig.283a, and 1929, p.337: Lord, 1927, p.15: Lord and Scott, 1924, pp.12,78: Scott, 1960, p.92: Scott, Glover and Southcott, 1974, p.267, unnumbered fig.: Andrews *in*: McDowall 1980, p.167, fig.30.1.
Pseudaphritis urvilli: Lord, 1923, p.69.

Note on second binomen

As is evident from the above table of synonymy, apart from what may be regarded as minor eddies such as those associated with Castelnau's *bassii*, the general current of Australian taxonomy (in which a paper (1960) by the writer joined) has accepted as the second binomen for this fish the 1831 *urvillii* of Valenciennes; and this identification persists in the latest text (Andrews, *in*: McDowall 1980). However, near the end of the last century Ogilby (1898), who had earlier (1890) given a redescription of Castelnau's *P. bassii* (emending *bassii* to *bassi*), observed at the conclusion of a detailed review of the history of *Aphritis*, *Pseudaphritis* and allied genera, "If the suggestion here made that *Eliginus bursinus* [footnote gives reference to 'Cuvier & Valenciennes', 1830 — the relevant volume, 5, is by Cuvier] is identical with *Aphritis urvillii*, be correct, our fish will have to be called *Pseudaphritis bursinus*. *E. bursinus* was said to have been collected by Quoy and Gaimard in Port Jackson during their first voyage to the southern hemisphere in the Uranie; it has not since been recognized."

While the Check-List (McCulloch 1929) obviously included an entry "*?Eleginus bursinus*" (McCulloch has clearly been earlier exercised by the problem, leading him in his catalogue of New South Wales fishes and fish-like animals (1922) to take the step, unusual in that work, of expressly noting an unresolved taxon), the recognition of *urvilli* remained the rule, and even the exceptional adoption by Scott (1962) in his catalogue of South Australian fishes of *bursinus* was negated in the second edition of the work (1974; in collaboration with Glover and Southcott). However, *bursinus* has been accorded formal status by Whitley in his definitive name-list of fishes recorded from Australia (1964). In the century and a half since the description by Cuvier of *Eleginus bursinus* from Port Jackson it would appear no fish referable to it other than the present fish has been reported, and despite some discrepancies in the reported fin counts there seems a high degree of probability that Valenciennes' *Aphritis urvillii* is a junior synonym of it: this view is adopted here.

Vernacular name

The book name Congolli, which has also some general currency in the southern mainland States, remains a purely formal designation in Tasmania, where the two names in actual common use are those given in our State lists from the earliest of these onward, namely, Sandy, Freshwater Flathead.

Material

In March and April 1981 the internation organisation Earthwatch and the Queen Victoria Museum, Launceston jointly conducted three expeditions to a little known part of the western coast of Tasmania, with base camp at Brooks Creek 29 km south of the Arthur River. Among the fish material collected and now deposited in the Museum was the following series of 15 specimens of *Pseudaphritis bursinus*: (a), (b), *Ls* 117.5,117, Smiths Gulch collected 23/03/81 ± 7 days, Q.V.M. Reg. No. 1981/5/22; (c), *Ls* 71, Brooks Creek, 23/03/81 ±7 days, Reg. No. 1981/5/23; (d)-(h), *Ls* 67,66,60.5,49,44, 07/03/81 ± 7 days, Reg. No. 1981/5/12; (i)-(o), *Ls* 179.5,169,144,154,104.5,70,56, Broots Creek, 18/04/81 ± 7 days, Reg. No. 1981/5/30.

Material previously in the Museum's collections that has also been examined comprises: (ma), (mb), *Ls* 185, 255, no locality, Reg. No. 871b; (mc), (md), *Ls* 140, 147, Denison River at Wyena, Reg. No. 1957/5/3; (me), *Ls* 187, Gawler River at Ulverstone, 1955/5/6; (mf), *Ls* 265, Tamar River at Beauty Point, 1967/5/17; (mg), *Ls* 146, Welcome River, 1972/5/313; (mh), (mi), *Ls* 108,102 Stony Creek, West Tamar, 1976/5/62; (mj) Strahan, West coast, *Ls* 64, 1969/7/61; (mk), *Ls* 61, Ringarooma River, 1976/5/165; (ml), *Ls* 117, mouth of Ringarooma River, 1974/5/40; (mm), *Ls* 205, Bridport, 1974/5/40; (mn) Gawler River, *Ls* 115, 1979/5/47; (mo)-(ms), Gawler River, *Ls* 120,114,108.5,103,103, 1978/5/29; (mt) North Esk at St Leonards, *Ls* 187, 1957/5/8; (mu), North Esk at Killafaddy, *Ls* 127, 1953/5/1; (mv) (mw), *Ls* 162,154, St Helens, 1955/5/1; (mx), (my), *Ls* 103,99.5, 5 miles (8 km) west of Tomahawk, 1962/5/9.

Scope of inquiry

The expeditions' material has been studied somewhat intensively, with special reference to body form, differential growth, relative lengths of head trunk tail, location of vertical fins, lengths of rays and spine of ventral as functions of their serial numbers and of general body form, coloration, while the material previously in the Museum's collections has yielded some additional data relating principally to meristic characters and proportions.

Meristic characters

The most recent treatment of the species (Andrews *in*: McDowall 1980) gives the formulae for the vertical fins as D. VII-VIII, 19-22, A. II, 21-22: however, a total of 25 radial elements in the anal is accepted in the local catalogues of Johnston (1883, 1891), and Lord and Scott (1924) and is depicted in the original figure (Cuvier 1830, pl.243 — reproduced in Waite (1921, fig.221, 1923, unnumbered fig.) and in McCulloch (1922, pl.47, fig.283a) — and in the replacement figure of Waite (1924, pl.30, fig.1). No counts transgressing these limits were encountered in our material. Apart from a range of 17-18 reported in Part IX (1960) the pectoral is regularly described and depicted as consisting of 18 rays (Castelnau 1872, Ogilby 1890, Waite 1924, Scott 1962, Scott *et al*. 1974, Andrews *in*: McDowall 1980): in the Earthwatch material we count in 30 fins (17(7), 18(16), 19(7). V. I, 5. The caudal count is conventionally 14; however, in some cases only 12 rays can be satisfactorily identified as main rays. A synoptic range by Andrews, taking account of all published accounts, sets the lateral line scales at 59-65: the Earthwatch sample yields 59(1), 60(3), 61(1), 62(5), 64(1), 65(2), 66(2), the last entry thus extending the limit upward. No reference appears to be made in local texts, apart from an observation in Part IX (1960), to the continuation of specialized scales beyond the hypural joint on to the caudal base, it being noted in that contribution that in the two fish examined there were 7, 10 tubules extending for nearly half the length of the caudal fin: in the present sample there are 2(2), 3(3), 4(2), 5(2), 6(1), 7(3), 8(1), 10(1) posthypural tubules. For l. tr., given by Castelnau as 6/14, by Ogilby as 6/15, we find 5-8 (modally 6)/14-18 (modally 15 or 16).

Dimensions

A comprehensive set of 41 measurements of the 15 Earthwatch specimens is specified in Table 3, data for each dimension comprising range, mean, standard deviation, coefficient of variation, all dimensions other than standard length (which is recorded in mm) being given as millesimals of standard length. Measurements of individual specimens are recorded in Appendix No. II.

Measurements of standard length, total length, length to vent, length of head, length of pectoral, length of ventral, maximum depth, depth of caudal peduncle made for the 25 specimens constituting the earlier material in the Queen Victoria Museum's collections are recorded in Appendix No. III.

Proportions

The present paragraph notes 11 body ratios as exhibited by the 15 individuals of the Earthwatch series, each proportion being specified by range, mean with standard error, standard deviation, coefficient of variation, in that order. Head in standard length 3.0-3.8, 3.43 ± 0.0590, 0.229, 6.7. Maximum depth in standard length 5.6-5.7, 6.46 ± 0.131, 0.506, 7.8 Depth of caudal peduncle in head 3.1-4.3, 3.54 ± 0.0885, 0.342, 9.7. Length to vent in standard length 1.8-2.5, 2.14 ± 0.0476, 0.184, 8.6. Eye in head 4.3-6.7, 5.3 ±0.216, 0.835, 15.9. Eye in snout 0.9-2.0, 1.21 ± 0.0850, 0.329, 27.1. Interorbital in eye 1.1-2.2, 1.67 ± 0.0969, 0.375, 22.5. Snout in head 3.2-5.1, 4.42 ± 0.132, 0.512, 11.6. Pectoral, measured from anterior border of root beneath operculum, in head 0.9-1.2, 1.05 ±0.0200, 0.0774, 7.3: length of median pectoral ray in head 1.2-1.6, 1.43 ± 0.0408, 0.141, 9.8. Length of ventral in head 1.1-1.8, 1.43 ± 0.0552, 0.214, 15.0. Length to first dorsal origin in standard length 2.2-3.1, 2.74 ± 0.0684, 0.265, 9.6. Length to second dorsal origin in standard length 1.8-2.1, 1.95 ± 0.0186, 0.0719, 3.7.

TABLE 3

PSEUDAPHRITIS BURSINUS (Cuvier, 1830)

Dimensions of 15 specimens, standard length 44-179.5 mm, collected by a joint Earthwatch-Museum Expedition to the West Coast of Tasmania in March and April 1981: range, mean, standard deviation and coefficient of variation. First line of table, standard length, in millimetres, all other lines as thousandths of standard length.

Feature	Range	$\bar{x}$	σ	V
Standard length, mm	44-179.5	96.0	43.44	45.2
Total length	1 134-1 390	1 206.2	61.80	5.1
Length to first dorsal origin	325-462	368.1	39.10	10.6
Length to first dorsal termination	388-529	455.7	42.23	9.3
Length to second dorsal origin	490-612	533.4	33.75	6.3
Length to second dorsal termination	838-925	889.0	24.01	2.7
Length to anal origin	430-562	496.6	36.36	7.3
Length to anal termination	852-982	904.7	36.02	4.0
Length to vent	394-546	470.1	39.68	8.4
Length to pectoral origin	182-279	216.2	28.28	13.1
Length of pectoral	231-306	278.5	24.04	8.6
Length to ventral origin	159-276	223.2	30.36	13.6
Length of ventral	156-269	208.9	33.55	16.1
Head	261-330	292.7	19.07	6.5
Length to preopercular border	143-229	183.3	20.74	11.3
Snout	55-95	67.0	11.33	16.9
Eye	47-70	56.7	7.65	13.5
Interorbital	28-43	33.1	5.15	15.2
Length of maxilla	64-107	79.4	14.15	17.9
Length to origin of upper caudal lobe	932-1 000	966.7	24.13	2.5
Length to origin of lower caudal lobe	910-1 000	952.9	27.20	2.9
Depth at front of eye	61-100	91.3	11.44	14.1
Depth at back of eye	89-148	106.3	16.3	15.4
Depth at operculum	127-166	144.8	11.85	8.2
Depth at first dorsal origin	132-170	152.5	12.84	8.4
Depth at first dorsal termination	138-169	153.3	10.18	6.6
Depth at second dorsal origin	141-164	153.5	7.27	4.7
Depth at vent	134-172	153.9	11.42	7.4
Depth at anal origin	134-169	151.9	10.20	6.7
Depth at second dorsal termination	82-104	89.5	8.05	9.0
Depth at anal termination	63-96	79.2	8.03	10.1
Maximum depth	134-180	155.7	12.24	7.9
Depth of caudal peduncle	75-93	83.1	67.56	8.1
Width at first dorsal origin	106-170	139.8	19.85	14.2
Width at first dorsal termination	101-164	135.9	20.51	15.1
Width at second dorsal origin	94-152	127.1	19.84	15.6
Width at vent	106-155	131.0	17.33	13.2
Width at anal origin	99-155	128.6	20.36	15.8
Width at second dorsal termination	32-68	47.4	11.72	24.7
Width at anal termination	29-60	42.0	10.60	25.2

Among the above ratios positive correlation with *Ls* at better than P 0.01 is exhibited by eye in head (r 0.955, z 1.887), eye in snout (r 0.929, z 1.655), caudal peduncle depth in head (r 0.842, z 1.229). Negative correlation with *Ls* at better than P 0.01 is exhibited by maximum depth in standard length (r -0.799, z -1.097), snout in head (r -0.709, z -0.884), length to first dorsal origin in standard length (r -0.884, z -1.393). It is of interest to note that with overall growth relative maximum depth and relative depth at caudal peduncle tend to vary in opposite senses.

Some similar ratios derived from the less extensive series of measurements made of the larger sample of the earlier Museum material, which exhibit some interesting variations, are recorded in Appendix No. IV.

Size

The range in standard length of the 15 Earthwatch specimens is 44-179.5 mm, in total length 53.2-215.5; the ranges for the 25 original Museum examples 61-265, 77-306. Some assessments of the maximum size attained by this species: 14 inches [356 mm] Waite 1921), 12 inches [305 mm] (McCulloch 1922), 250 mm (Lord and Scott 1924), 360 mm (Scott *et al.* 1974), "examples up to 300 mm known but usual size around 150-200 mm" (Andrews *in*: McDowall 1980). Of his material of *Eleginus bursinus* Cuvier noted "Notre plus grand individu n'a que six pouces."

Size classes

Nothing appears to be known of the growth rate. A provisional classification of the Earthwatch sample of 15 individuals would suggest the recognition of three size (age?) groups: (a) 8 specimens, *Ls* 44, 49, 56, 60.5, 66, 67, 70, 71, $\bar{x}$ 60.4; (b) 3, *Ls* 104.5, 117, 117.5, $\bar{x}$ 113.0; (c) 4, *Ls* 134, 144, 169, 179.5, $\bar{x}$ 156.6. Support for this dissection is provided by the fact that in all save one (length to hind caudal margin) of the 12 length-to dimensions set out in table 4 as being functions of overall size there is found a consistent increase (or in last entry decrease) in magnitude for the variates (a) (b) (c) in that order (most other dimensions investigated follow the same sequence). The probable homogeneity of the accepted classes is further indicated by the sizes of the relevant coefficients of variation: for (a) V = 16.5, (b) 6.5, (c) 13.5; while (a) + (b) and (b) + (c) yield decidedly higher values, 34.6, 20.3 (calculations with d.f. n-1).

Differential growth along anteroposterior axis

While consistency of the sequence (a)>(b)>(c), or (a)<(b)<(c), obtains, in respect of length-to measurements, it is not to be expected with such small samples that the interclass increments should exhibit quantitative regularity, and accordingly it has been deemed expedient in considering differential growth along the general anteroposterior axis of the fish to pool classes (b) and (c), giving subsample *A* with 8 specimens of *Ls* 49-71 mm and subsample *B* with 7 of *Ls* 104.5-179.5.

It is found that at 11 of 12 selected sites on the axis the mean length to the point, assessed as a millesimal of standard length, in *B* exceeds that in *A*, the change of sense occurring beyond the origins of the caudal ridges, somewhat in advance of the hypural joint. This growth gradient exhibits two segments: for the first three entries the mean value of *B* as a percentage of that of *A* decreases from 118.0 (at origin of pectoral) to 107.6 (at opercular margin); for the remaining entries, excluding the final entry for total length, it decreases from 115.2, (at first dorsal origin) to 100.2 (at mean of upper and lower caudal ridge origins). The data are set out in table 4 and the general nature of the gradient is shown graphically in fig.7. The decrease caudad is statistically significant in both segments.

Length of head, length to vent, standard length

It is found that in a loglog plot these three basic dimensions are linear, with high statistical significance, on {1,2,6} (Appendix No. V).

TABLE 4

PSEUDAPHRITIS BURSINUS (Cuvier, 1830)

Relative growth as indicated by lengths recorded as thousandths of standard length to selected points along anteroposterior axis in a pooled sample from the West Coast, Tasmania: subsample *A* of 8 specimens of standard length 49-71 $\bar{x}$ 60.4 mm, subsample *B* of 7 of standard length 104.5-179.5 $\bar{x}$ 137.9 mm. Estimates of $B\bar{x}$ as percentage of $A\bar{x}$ derived from two equations in the text.

Feature	Subsample *A*		Subsample *B*		$B\bar{x}$ as percentage of $A\bar{x}$		Total sample: correlation with *Ls*	
	Range	$\bar{x}$	Range	$\bar{x}$	Measured	Estimated	*r*	*z*
Length to: origin of pectoral	182-229	198.8	204-279	234.4	118.0	118.9	0.838***	1.213
: origin of ventral	159-249	205.3	222-276	243.7	118.7	117.7	0.716**	0.899
: opercular margin	261-307	282.6	285-330	304.1	107.6	107.7	0.605*	0.701
: first dorsal origin	325-364	343.7	344-462	396.0	115.2	116.3	0.804***	1.111
: first dorsal termination	388-457	424.3	459-529	491.6	115.9	112.3	0.782***	1.051
: vent	394-500	446.9	453-546	496.6	111.1	111.4	0.597*	0.688
: anal origin	455-523	476.8	479-562	519.3	108.9	110.4	0.523*	0.581
: second dorsal origin	490-543	522.0	526-612	559.0	107.1	109.0	0.817****	1.149
: second dorsal termination	838-941	880.9	863-925	920.4	104.5	103.4	0.539*	0.602
: anal termination	852-916	881.3	880-982	931.6	105.7	103.4	0.570*	0.648
: caudal ridge origins, mean	915-1 000	955.9	910-985	957.8	100.2	102.7	0.090	0.091
: hind caudal margin	1 134-1 243	1 213.0	1 137-1 243	1 198.4	98.8	—	−0.263	−0.281

Location of dorsal fins relative to caudal base

In a loglog plot the length-to set {length to origin, to termination of first dorsal, to origin, to termination of second dorsal, to origin of caudal (*Ls*)} is significantly linear on the integer set {3,4,5,9,10} (Appendix No. VI).

Location of anal fin relative to caudal base

In a loglog plot the length to origin of anal, to termination of anal, to caudal origin (*Ls*) is significantly linear on the integers {3,8,10} (Appendix No. VII).

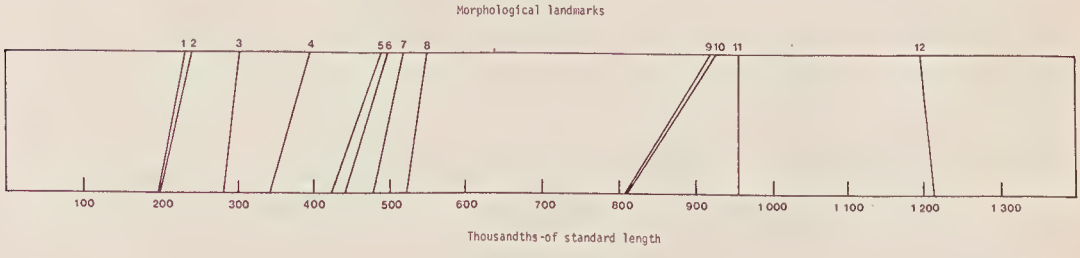

FIG. 7 - *Pseudaphritis bursinus* (Cuvier, 1830). Relative growth as indicated by lengths to selected points in a sample from the West Coast, Tasmania. Lower line subsample A, 8 specimens, mean standard length 60.4 mm; upper line subsample B, 7 specimens, mean standard length 137.9 mm. Points of measurement: length to 1 pectoral origin, 2 ventral origin, 3 opercular margin, 4 first dorsal origin, 5 first dorsal termination, 6 vent, 7 anal origin, 8 second dorsal origin, 9 second dorsal termination, 10 anal termination, 11 caudal ridges origins (mean), 12 hind caudal margin.

Ventral fin

Two interesting length patterns are exhibited by the radial elements of this fin, one involving their lengths and their serial numbers, the other being a relation between their length and the depth of the fish at specified points along the general anteroposterior axis: these two patterns are discussed below. Following the convention adopted in Part XXI (1974) the ray furthest from the spine (most postaxial) is counted as the first; while the spine is here conveniently taken as being homologous with the soft rays and thus treated as the sixth radial element overall.

Length-number pattern in ventral

The radial elements exhibit a characteristic length-number pattern in two sets, the lengths of {1,2,3} being linear, in a loglog plot, on their serial numbers and {6,5,4,3} being linear, in a loglog plot, on {1,2,3,4}, respectively: it will be observed the sets intersect, with ray 3 the common member. The parameters of the equation $L = bN^k$ rectified as $\log L = k \log N + \log b$, together with its statistical significance and the estimated and measured length, recorded as millesimals of standard length, for each of four individuals are set out in table 5. Calculations for some further specimens have been found to give similar results. (The present pattern is an unusual one; in that commonly encountered the lengths of rays 1, 2, 3, 4 are linear, in a loglog plot, on their serial numbers 1, 2, 3, 4; no special length-number relation for the spine and ray 5 being apparent). While im most instances the corresponding ray elements of the right and left fins are subequal in length, it is of interest to note that when such is not the case, as in specimen (1) (in which the first ray of the right is 11% longer than that of the left), nevertheless both fins are specifiable by the one equation, though with markedly different parameters (slope of right 1.9 that of left).

TABLE 5

PSEUDAPHRITIS BURSINUS (Cuvier, 1830)

Length-number relations of ventral ray elements: $L = bN^k$ where L = length of element, N = a natural number; equation rectified in two sets, L = {ray 1, 2, 3} N = {1, 2, 3}, L = {spine, rays 5, 4, 3} N = {1, 2, 3, 4}. Lengths in millesimals of standard length, *TLs*.

Specimen	Standard length, mm	Fin	Ray elements	Slope	Intercept	t	Estimated (measured) length, *TLs*
			1,2,3	0.2311	2.1944	33.319	156(157) 184(183) 202(202)
		Right	5,5,4,3	0.4272	2.0445	27.247	111(112) 149(149) 176(175) 200(202)
			1,2,3	0.2565	2.1812	19.977	152(152) 181(180) 201(202)
(n)	134	Left	5,5,4,3	0.4278	2.0442	22.950	111(112) 149(146) 177(178) 200(202)
			1,2,3	0.2421	2.1449	16.895	140(139) 167(167) 182(181)
		Right	5,5,4,3	0.4333	1.9964	93.408	99(99) 134(133) 160(160) 181(181)
			1,2,3	0.2643	2.1435	31.114	139(139) 167(168) 186(185)
(m)	144	Left	5,5,4,3	0.4372	2.0074	23.750	102(101) 138(141) 164(163) 186(185)
			1,2,3	0.6776	2.1873	29.850	154(154) 161(162) 165(166)
		Right	5,5,4,3	0.4229	1.9657	9.499	92(91) 124(131) 147(143) 166(166)
			1,2,3	0.3615	2.0837	9.067	139(139) 161(160) 176(178)
(l)	169	Left	5,5,4,3	0.5229	1.9392	23.571	86(86) 125(128) 154(154) 179(178)
			1,2,3	0.2408	2.1139	9.056	130(129) 154(156) 169(168)
		Right	5,5,4,3	0.5723	1.8723	23.886	75(76) 112(111) 140(137) 166(168)
			1,2,3	0.2010	2.1108	6.364	129(128) 148(151) 161(159)
(ma)	185	Left	5,5,4,3	0.5040	1.8893	23.846	78(78) 110(108) 135(133) 156(159)

Ray lengths of ventral and body depth

When the lengths of the six ray elements are plotted against six equidistant measurements of the height of the dorsal profile above the anteroposterior axis of the fish from snout tip to middle of caudal peduncle at level of hypural (these heights being obtained either by direct measurement or in the case of the large individual from the Museum's old collection, (ma), by calculation from the equation for the profile recorded in Appendix No. VIII), it becomes evident one straight line results from joining the three points 2, 1, 6 and another from joining the four points 3, 4, 5, 6. Since the slopes of the lines for the two sets do not differ greatly — divergence most marked in (n) — it is not inappropriate to calculate a single equation for the pooled set {1-6}, and this has been done (table 6). If measurements for the divergence of the ventral profile from the median anteroposterior axis of the fish are substituted as abscissal values for those for the divergence of the dorsal profile, a similar pattern is apparent for the same sets {2, 1, 6} and {3, 4, 5, 6}. However, while in two individuals, (1) and (ma), the slopes for these sets resemble those with the dorsal measurements as abscissae in being of tolerably similar magnitude, in the two other individuals they exhibit marked disparity (1.00, 2.07; 0.98, 1.51): accordingly data for the pooled set {1-6} have not been recorded in the case of the ventral series.

TABLE 6

PSEUDAPHRITIS BURSINUS (Cuvier, 1830)

Lengths of the 6 ray elements of the pelvic (1 = most postaxial ray, 6 = spine) on 6 equidistant measurements of height of dorsal profile above and depth of ventral profile below an anteroposterior axis from tip of snout to middle of caudal peduncle at level of hypural joint: $L = mB + c$, where L = ray element length, B = height or depth of body as specified. All dimensions as millesimals of standard length.

Specimen	Standard length	Body profile	Ray elements	$L = mD + c$ m	c	t	Body depth, D	Ray element length, L: estimated (measured)
			2,1,6	4.07	−62.90	8.339		184(182) 150(155) 114(112)
			3,4,5,6	5.44	−126.89	11.867**		198(202) 178(177) 153(148) 109(112)
		Dorsal	1-6	4.80	−96.32	12.895**	52.2 60.4 59.7 56.0 57.5 43.3	154(155) 194(182) 190(202) 173(177) 151(148) 112(112)
			2,1,6	1.00	67.83	17.190*		180(182) 156(154) 111(112)
(n)	134	Ventral	3,4,5,6	2.07	19.99	17.830**	88.8 119.9 86.6 76.1 63.4 43.3	199(202) 178(177) 151(148) 110(112)
			2,1,6	1.99	27.37	32.691*		168(168) 138(139) 101(100)
			3,4,5,6	2.19	24.99	22.453**		188(183) 157(162) 131(137) 106(100)
		Dorsal	1-6	2.04	30.27	8.508**	55.6 70.8 74.3 60.4 48.6 36.8	144(139) 175(168) 182(183) 153(162) 129(137) 103(100)
			2,1,6	0.98	62.54	9.563		165(168) 143(139) 99(100)
(m)	144	Ventral	3,4,5,6	1.51	47.17	14.478**	81.9 104.2 90.3 77.1 56.3 36.8	183(183) 163(162) 132(137) 103(100)
			2,1,6	4.20	−85.84	8.661		158(161) 150(147) 88(89)
			3,4,5,6	4.12	76.33	280.327***		168(168) 146(146) 119(119) 95(95)
		Dorsal	1-6	4.13	−76.33	31.861***	56.2 58.0 59.2 53.9 47.3 41.4	156(147) 163(161) 168(172) 146(149) 119(130) 95(89)
			2,1,6	1.09	43.21	271.268**		161(161) 147(147) 88(89)
(1)	169	Ventral	3,4,5,6	1.09	44.4	20.600**	94.7 107.7 118.3 94.7 76.9 41.4	173(172) 148(149) 128(130) 90(89)
			2,1,6	2.72	−8.25	10.903		156(154) 124(129) 76(74)
			3,4,5,6	2.55	−9.23	7.305*		155(165) 141(135) 117(110) 70(74)
		Dorsal	1-6	2.58	−7.36	6.051	48.8 60.5 64.5 58.9 49.7 39.6	119(129) 149(154) 159(165) 145(135) 121(110) 72(74)
			2,1,6	0.92	44.35	34.241*		157(154) 123(129) 76(74)
(ma)	185	Ventral	3,4,5,6	0.99	40.55	10.104**	86.3 122.3 122.5 99.5 66.0 34.6	162(165) 140(135) 106(110) 75(74)

The parameters of the equation $L = mB + c$ (L = ray element length, B = height or depth of body as specified above) for the material discussed in the preceding paragraph are exhibited in table 6, together with height and depth measurements, estimated and measured lengths of ray elements (all dimensions as millesimals of standard length) and an indication of statistical significance. So far as the writer is aware a relation of this type subsistent between the form of the ventral fin (as specified by the lengths of its ray elements) and the body form of the fish has not previously been reported (certainly not for the present species). Unpublished information on some other species suggests profiles of other fins and body profiles may be specifiable each in terms of the other. In Part XXVII (1981), it was shown that in the scombrid (*s.l.*) *Gasterochisma melampus* Richardson, 1845 the heights of dorsal and anal finlets are correlated with corresponding heights and depths of the dorsal and ventral body contours, a formulation confirmed for that species in the present contribution.

Dorsal and ventral profiles

Ten measurements at equal intervals along an anteroposterior axis from the most advanced point of the snout to the middle of the caudal peduncle at the level of the hypural joint have been made of height, H, of fish above and depth, D, below this line for two large specimens in the original Museum collection, (ma) *Ls* 185 (mb) *Ls* 255. In both fish the dorsal increases to a maximum at the fifth decile, the first five deciles accounting for 0.41, 0.53 of the total. In the ventral profile the maximum occurs at the fourth decile in the smaller fish but noticeably earlier, at the second, in the larger, the first five deciles representing slightly greater proportions of the total than in the dorsal profile, 0.59, 0.58. For the smaller specimen the sequence of magnitude of the deciles of height is 5 > 4 = 6 > 3 > 7 > 8 > 2 > 9 > 1 > 10: the same pattern occurs in the larger example save that here 6 < 3. For the depth deciles 4 > 3 = 5 > 6 > 2 > 7 > 8 > 1 = 9 > 10 and 2 > 3 > 4 > 5 > 6 > 1 > 7 > 8 > 9 > 10.

Polynomials specifying the dorsal and ventral profiles as thus defined have been calculated (Appendix No. VIII).

Width

Widths at ten equal intervals have been measured for (ma) and (mb). Polynomial equations are recorded in Appendix No. IX.

The sequence of decreasing magnitude of the deciles is in each case 3, 4, 2, 5, 6, 1, 7, 8, 9, 10, the largest being 1.3, 1.6 the first, 4.2, 4.5 the last, with the anterior five contributing 0.65, 0.64 of the total. Widths of the Earthwatch sample (together with depths) have been measured not at equal intervals but at a series of morphological landmarks: means and ranges are recorded in table 4 (for individual measurements see Appendix No. III).

Width as a function of depth

A precise and interesting relation subsists between width and depth. With ten widths measured at equal intervals along standard length plotted against ten depths similarly measured, the two large well-preserved Museum specimens (ma) and (mb) yield the graphs shown in fig.8a, each presenting an upwardly convex curve for the early deciles and an upwardly concave curve for the later deciles. Each of the two segments of each graph represents a logarithmic arc such that $\log W = mD + c$, this linear relation (equations, Appendix No. X) being presented in fig. 8b. It may be noted that in (ma) the 1-3 arc on extrapolation becomes continuous with the 4-10 arc, yielding a sublenticular graph with a notable resemblance in overall form to a plot of fin borders on body profile encountered in an unpublished study of a scombrid (*s.l.*) *Thunnus maccoyii* Castelnau, 1872. Thus the sampling of the situation with the grid employed (unit, one-tenth of standard length) is such that in the case of one specimen (ma) the point of change of the graph (from upwardly concave to upwardly convex) falls on the relevant length-decile (7th), while in (mb) it is missed by the grid measurement, merely occurring in its vicinity.

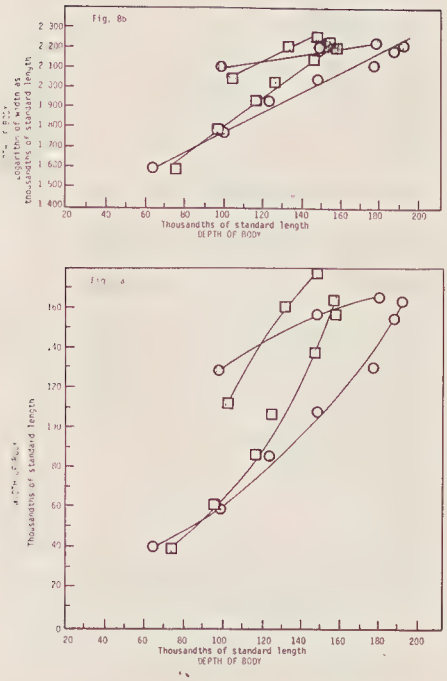

FIG. 8 - *Pseudaphritis bursinus* (Cuvier, 1830). a: Sublenticular curve of width of body at 10 equidistant points on depth of body at 10 equidistant points: circle, specimen (ma), standard length 185 mm; square, specimen (mb), standard length 255 mm. b: Linear graphs of logarithms of these arcs on depth of body: circle, (ma); square, (mb).

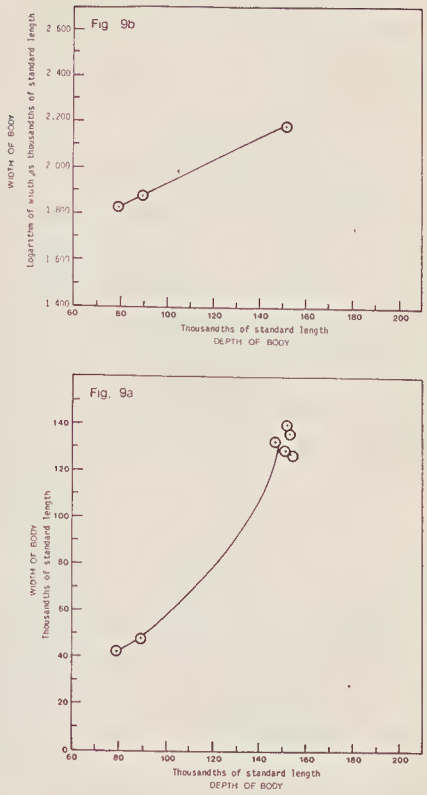

FIG. 9 - *Pseudaphritis bursinus* (Cuvier, 1830). a: Curve of width of body at certain morphological landmarks on depth of body at same points. b: Linear graph for logarithmic values of points 7, 6, 5 on depth of body at same points. Landmarks: length to 1 first dorsal origin, 2 first dorsal termination, 3 second dorsal origin, 4 vent, 5 anal origin, 6 second dorsal termination, 7 anal termination. (Earthwatch material.)

Decile measurements of depth and width were not made for the Earthwatch sample, but these dimensions were recorded at seven significant points along the general anteroposterior axis, namely, in sequence caudad, first dorsal origin, first dorsal termination, second dorsal origin, vent, anal origin, second dorsal termination, anal termination. The result of plotting mean width against mean depth for the 15 individuals is shown in fig. 9. The first four variates, located tolerably close together on 0.4-0.5 of the standard length yield merely a cluster of points: on the other hand the three variates, anal origin, second dorsal termination, anal termination, which cover 0.5-0.9 of the standard length are capable of being joined to give an upwardly concave arc similar to that noted above a joining the posterior decile measurements for the large specimens (ma) (mb). Like that arc it satisfies the relation $\log W = mD + c$ (Appendix No. X).

Form as depicted in figures

Published figures raise several questions: none is wholly satisfactory. Those considered here are the original figure (Valenciennes 1831, pl.243) of *Aphritis urvillii* based on the type material of that (synonymic) species, a substitute figure by Waite (1924, pl.30, fig.1) of a Tasmanian example 215 mm in length, a drawing in Andrews (*in*: McDowall 1980): in the subjoined comments these are designated V, W, A, respectively.

(a) Postdorsal membrane. In V there is depicted behind the last spine of the dorsal a small unpigmented apparently delicate subtriangular membrane connecting it to the dorsum, its horizontal subequal to its vertical extent (in early Australian texts, e.g. Waite (1921, 1923) McCulloch (1922) this figure has fared so poorly in reproduction that this feature is barely visible, and was indeed earlier (1960) overlooked by the writer in these sources). In Part IX (1960: 93) it was reported that in two examples, *Ls* 75, 80.5, from George Bay, east coast, the first dorsal (but no other vertical fin) was broadly connected behind to the body by a membrane constituting 4.0 mm (subequal to eye) of a total base of 12.1. In an extensive series, collected over several months, from the North Esk, near Launceston, in which river, after an absence of two or three decades, this species suddenly appeared in abundance in 1957-58, a postdorsal membrane was regularly present. Such a membrane could readily be damaged or destroyed during collection and preservation. Examination of the Earthwatch material shows in several a small (? residual) area of membrane, in the majority a white fleshy strip adherent to the dorsum in the interdorsal region (probably interpretable as the remains of a membrane), in several no additional structure of any kind. No such membrane is represented in either W or A, the dorsal ending sheerly at its last spine.

(b) Eye. In V the eye just fails to reach the dorsal profile, in W it is set somewhat lower, in A it projects markedly above the interorbital. Castelnau (1872, p.92) stated of his (synonymic) *P. bassii* "eye placed obliquely in the superior part of the head"; of the 1960 Tasmanian material it was noted "in strict lateral view, eye cuts profile"; Andrews observed, eyes "almost on top", "on top" of head. In the Earthwatch material the position in order of frequency is upper rim of orbit slightly above, just touching, moderately above, slightly below profile (no specimen as markedly projecting as in A).

(c) Lateral line. On the evidence afforded by the present material (and the 1960 specimens as described) the position of the lateral line is not satisfactorily depicted in any of the three illustrations, all of which place it, at least in some part of its course, too far below the dorsal profile. At first dorsal origin, second dorsal termination, origin of upper caudal ridge, origin of middle caudal rays its distance from the ventral profile is modally about 3-3.25 (exceptionally 2.8), 3 (exceptionally 2.66), 2, 1.2 (to 1.5) times its distance from the dorsal profile: approximate values for V are <3, 1.5, 1.2, ≤1, for W 2.25, 3, <2, ≤1, for A 2.66, 1.25, 1.2, ≤1. Only W gives any indication of characteristic short downturn shortly behind level of end of soft dorsal; the short predorsal rise is recognizable only in A.

(d) Upper jaw. In V the shaft of the maxilla is evident right to the dorsum of the snout, further than it is normally in view, in W the premaxilla is not carried sufficiently far back; in A the hind end of the jaw lacks the characteristic broad expansion and no clear distinction between maxilla and premaxilla is apparent. (e) Opercular angle. The upper border varies from slightly to moderately concave; in A about linear. The lower border presents a small but distinct notch; shown in V but not in W or A. (f) Pectoral. In some individuals the upper border is evenly convex as in W, in others it presents two subequal almost straight segments with a well rounded junction as in V; junction too acute in A. (g) Ventral. The evenly convex distal border is shown slightly concave in ; the sharply pointed form of the fin is not apparent in A. (h) Anal. The origin is correctly depicted in W as being in advance of second dorsal by one or two rays, is somewhat too anterior in V at middle of interdorsal, is much too advanced in A under first dorsal termination. The termination of the fin lies behind that of the second dorsal by about 4 rays, as in V and W; in A too far forward, level with dorsal termination (in text

"originates beneath last rays of first dorsal"). (i) Caudal. The original specification of the caudal of *Aphritis urvillii* was "coupée carrément"; no specification was provided for *Eleginus bursinus*. In a good description of a Victorian example (as *Aphritis bassi* — *bassi* an unjustifiable emendation for *bassii*), which remains perhaps the best published account of the present species, Ogilby (1890: 69) gives "crescentic". Andrews has "slightly rounded", though his figure shows the fin as emarginate. The modal degree of convexity approximates that indicated in Waite's figure, tending to be less than that in Valenciennes'. However, an occasional individual exhibits a distinctly concave border, this being particularly noticeable in Museum material from the Gawler River.

Coloration

The treatment of coloration in the original description of *Aphritis urvillii* is brief; fuller accounts appear in the original description of Castelnau's *Pseudaphritis bassii* (which gives an indication of colors in life) and in a redescription of that species by Ogilby (1890: 67). In offering a new figure Waite (1924) called attention to some deficiences in Valenciennes' plate, notable the omission of two dark stripes, with cross bars, along the flank, the absence of dark markings on the upper part of the pectoral and the presence of more than three rows of spots in the caudal. He noted also a feature not previously reported, "spots" [= dashes] on the outside of the ventral. No attempt to indicate color pattern on the body is made in Andrew's figure. Descriptions by Castelnau, Ogilby and (apparently) by Waite each refer to a single individual. Some additional observations, based on the 15 Earthwatch examples, are here made.

The degree of development of the two lateral stripes that are such a characteristic feature of this species (the upper at times tending to blend with the general dark region above the lateral line) shows considerable variation, ranging from virtually a complete line to a variably definite series of disconnected units, subcircular, subelliptical (as in W), rectangular or linear. The light-colored interspaces between the bars connecting the stripes are commonly more sharply demarcated than as figured, and may take the form of black or blackish bordered rectangles or squares; modally 11-12, 2 wholly below pectoral. In young individuals the flank below the inferior stripe, yellowish immaculate in adult, tends to be whiter and less extensive vertically, and to show some, even heavy, stippling. The half dozen indistinct broad dark bars between the lateral line and the dorsal profile shown in W are in some of our examples much darker and more conspicuous, the hindmost being identifiable as the black spot or blotch regularly located at the caudal base. Quite small specimens (*Ls* ≤ 60 mm) possess 6 conspicuous evenly-spaced black saddles, not previously reported, their anteroposterior extensions subequal to their interspaces, the color extending to a variable degree on to the upper lateral surface, where in most cases it alternates with the dark lateral bars: in adults these tend to become indistinguishable in the general darkening of the whole dorsum.

Head marbled blackish and yellow (sides purple, in front of eyes red, Castelnau). The two black bars running obliquely down and back from the eyes, first noted by Ogilby and shown in W as discontinuous are usually traceable, and may become continuous and sharply defined, though, on the other hand, the upper one may become merged with a general postorbital darkness; a third oblique bar in advance of the eye, just indicated in W, is usually present. Interorbital commonly blackish, upper surface of snout light-dark grey. Lips either mainly dark, greyish or ivory behind, or mainly greyish, blackish behind; at times with some dark spotting or mottling. Ventral surface of snout with variable dark markings laterally; almost invariably some pigmentation along the isthmus, in young as punctuations only, in some larger examples as a sharply demarcated black stripe, its width about one-fourth its length, the latter twice eye. Branchiostegal membrane hyaline; rays off-white, exceptionally with some sparse pigmentation.

Each dorsal spine with 2-4, modally 3, spaced blackish lines (not spots as in V): All accounts speak of, and all illustrations show, first dorsal membrane as hyaline: in our material it regularly exhibits some pigmentation, the most constant feature being a pennon-like series of melanophores in each inter-radial panel, usually in its distal half, sloping down and forward, the broad end superior. Each ray of the soft dorsal presents two moities extending throughout its length, becoming noticeably apart distally; each ramus bears 3-4 spaced patches or, more commonly, lines of dark pigmentation — well shown in W,

not evident in V or A. The membrane, consistently described and figured as immaculate is indeed chiefly so; however, in most individuals there are some areas of pigmentation similar in form and location to those in the first dorsal but in general decidedly less developed with fewer melanophores. Anal as preserved white (pink, Castelnau); as described and figured, characteristically immaculate; rarely with some dark lines on the rays similar to, but less pronounced than, those on the dorsal spines. Almost invariably at least a blackish smudge, in most specimens a conspicuous spot on either side of the base of each anal ray. Pectoral much as in W, but the dark lines on the rays more pronounced, increasing in length outward, forming about 7 conspicuous arcs; commonly, as in W, not developed on several inferior rays, making the fin distinctly bicolor; exceptionally all rays may be pigmented, though in the lower ones only distally; a dark patch or patches at base of fin: no markings in V, in A no distinction between upper and lower rays. Markings on the ventral first noted and figured by Waite; these may be as shown or may form recognisable arcs of dark lines or smudges; regularly absent or poorly-developed in young. Waite criticized V as showing caudal with too few arcs of spots (3) and himself indicated about 7; Castelnau "yellow, with four or five transverse crimson bands", Ogilby, somewhat inexplicably, "purple with two transverse white bars on the posterior half". In the preserved West Coast material the white or pale grey rays each with 4-7 dark grey or blackish spots or lines, tending (a feature not evident in illustrations) to increase distally in longitudinal extent.

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NEW LOCALITY RECORDS AND PRELIMINARY INFORMATION ON DEMERSAL FISH FAUNAL ASSEMBLAGES IN TASMANIAN WATERS - ERRATA.

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ABSTRACT

LAST, P.R. and HARRIS, J.G.K., 1982 (31 viii): New locality records and preliminary information on demersal fish assemblages in Tasmanian waters — Errata. *Pap. Proc. R. Soc. Tasm.*, 116: 219. ISSN 0089-4703. Tasmanian Fisheries Development Authority, Taroona, Tasmania.

Corrections to the text and tables of the above paper are noted.

Page 191: paragraph 1, line 2:- delete comma after 'record'.
" paragraph 4:- heading should have brackets before 'Risso'.
Page 192: paragraph 6:- heading should have ü in 'Günther'.
Page 193: paragraph 8, line 1:- insert full stop after '*M*' in '*M. elevatus*'.
Page 194: paragraph 6:- heading '*Caerulea*' should read '*caerulea*'.
" paragraph 7:- site code: comma should be deleted after '6'.
Page 195: paragraph 2, line 3:- delete '150 fathoms'.
Page 196: paragraph 1, line 8:- '*Thamnoconus degini*' should read '*Thamnoconus degeni*'.
" paragraph 1, line 9:- '*Notopogo*' should read '*Notopogon*'.
" paragraph 2, line 2:- delete equal sign before '400'.
" paragraph 2, line 10:- insert full stop after '*innotabilis*'.
paragraph 5, line 4:- replace comma with semi colon after 'respectively'.
Page 197: paragraph 2, line 4:- insert 'and' after 'shelf'.
Page 198: in 'Iwamoto 1978' '*Ceolorinchus*' should read '*Coelorinchus*'.
" in 'Last 1978' 'Unpulb.' should read 'Unpubl.'.
Page 200: in 'Wolfe 1970' insert double quotation marks before "Urania".
Page 206: delete first four lines under species at top of table.
" delete first three rows of crosses at top of table.
Page 207: whole page becomes p.208.
Page 208: whole page becomes p.207.
Page 209: depth range 6, line 7:- 'Southern' should read 'Banded'.

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